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Voyager 1

Where next outside the Solar System?

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ISSUE 261 / NOVEMBER 2013

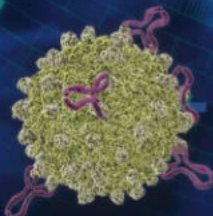


THE FUTURE OF US

How evolution will conquer disease, boost intelligence and prepare us for space travel

ATTACK ON YOUR BRAIN

How your own immune system could kill you



Q&A

- Should you pick the same lottery numbers every week?
- Is social media changing your brain?
- How does a pillow cure snoring?



BRITAIN'S ALIEN QUEST

New search for extraterrestrial intelligence



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WELCOME TO FOCUS



HAVE YOU HEARD of Alfred Russel Wallace? He independently came up with the theory of evolution, but he's not nearly as well known as Charles Darwin. Wallace gets some long-overdue recognition this month as events at the Natural History Museum mark 100 years since his death. In this issue, Prof Rebecca Stott celebrates Wallace and other pioneering evolutionists on p112.

All this talk of evolution had us wondering how humanity will change in the future. Today, of course, there aren't simply evolutionary pressures like resources and geography to consider. If we begin to augment our senses with electronic aids, the future for homo sapiens could be very different from our past. Hayley Birch investigates on p38.

Homo sapiens is the only intelligent species in the Universe – that we know of. The Search for Extra Terrestrial Intelligence (SETI) has been going on for years, but recently it's stepped up a gear with the announcement of a pioneering project in the UK. Paul Sutherland joins the hunt for ET on p91.

Talking of pioneering projects, did you hear about the proposed HyperLoop that would transport you from Los Angeles to San Francisco in just half an hour? On p48 we look at whether the idea is feasible, and bring you a whole host of other futuristic trains besides.

Enjoy the issue.

P.S.

Don't miss our December issue, on sale 14 November

Graham

Graham Southorn, Editor

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APPEARING IN THIS ISSUE...



Hayley Birch

Hayley is a science journalist and author whose work has appeared in *New Scientist*, *The Daily Telegraph* and *Nature Biotechnology*. Her biology background made her the perfect person to find out how the human race will evolve on p38.



Susannah Cahalan

Susannah is a journalist for the *New York Post* and the author of *Brain On Fire - My Month Of Madness*, which chronicles her battle with an autoimmune disease. She looks at what happens when the body attacks itself on p56.



Katharine Sanderson

Katharine is a science journalist and former news writer for the journal *Nature* who has a background in chemistry. On p64 she looks at how the world might change now that atmospheric carbon dioxide is approaching record levels.



Rebecca Stott

Rebecca is a broadcaster, writer and professor of literature whose non-fiction books include *Darwin's Ghosts* and *Darwin And The Barnacle*. She explores how our understanding of evolution evolved on p112.



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On p36, **David Canter** looks at some of the biggest questions still to be answered by forensic psychology

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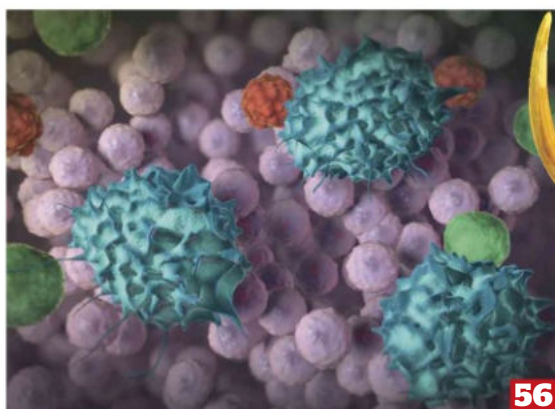
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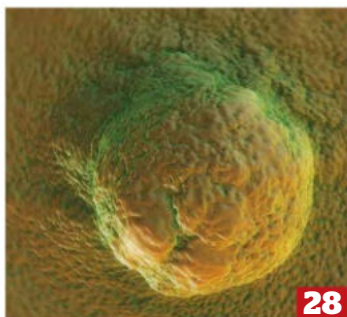
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Awe-inspiring images from the world of science

MegaPixel

Miniature mosaic

THIS DELICATE MOSAIC is the top of a butterfly's egg. It's the egg of an owl butterfly, or *Caligo memnon*, so named because of the spots on its wings that look like the eyes of an owl.

At the centre of the mosaic is the most important structure of the egg – the micropyle. This tiny, funnel-shaped hole carries sperm through the egg's tough outer layer and into the centre. "When butterflies mate, the male passes a package full of sperm and nutrients to the female," explains Dr Andrew Warren, collections manager at the Florida Museum of Natural

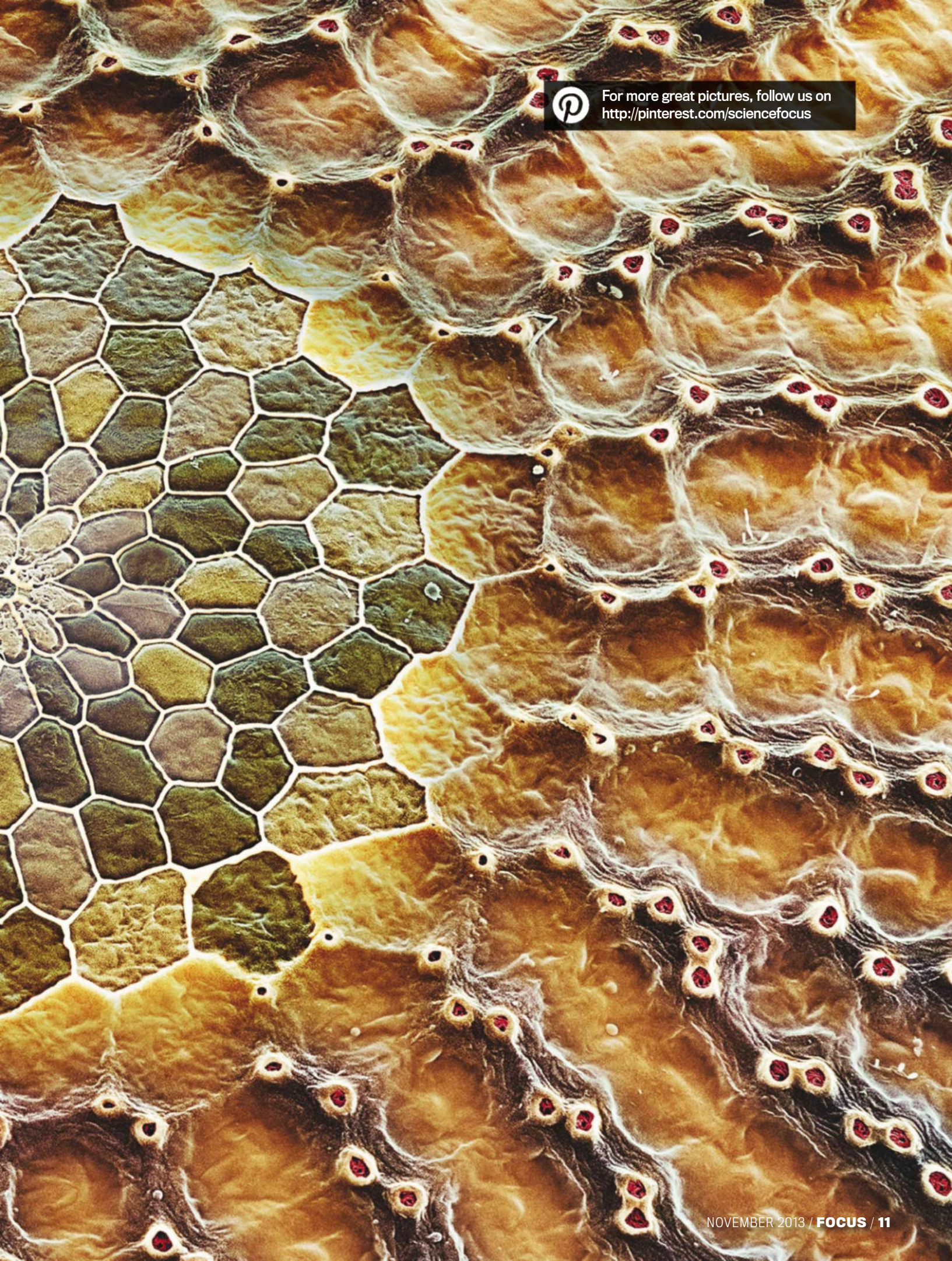
History. "Females store the sperm for several weeks. When it comes to laying the egg, the female fertilises it by inserting sperm into the micropyle, then deposits it."

Radiating out from the centre are the aeropyles. These small pores allow oxygen to get to the embryo, but are lined with spiky structures to prevent any bacteria from entering. The larva is protected until it hatches to begin its life as one of the largest butterflies in Central and South America, with a wingspan of up to 150mm (6 inches).

PHOTO: MARTIN OEGGERLI



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MegaPixel

Pink sky at night

THIS MAY LOOK like a magenta sun setting over some alien planet, but it's actually the Aurora Borealis here on Earth – in Oregon.

The Northern Lights appear in the night sky when charged particles from the Sun collide with molecules in Earth's upper atmosphere. The colours produced in these collisions depend on the molecules that are hit: oxygen molecules give off green and red light, nitrogen molecules red and blue. The pink hue seen here is a much rarer sight, and harder to

explain. "It may be the combination of different emissions at different altitudes," says Prof Jim Wild, Professor of Space Physics at Lancaster University. "So the high altitude blue emission of light from nitrogen mixes with the reds beneath it."

The fact that the Aurora is visible in Oregon, on the same latitude as northern Italy, is also startling, and signals a possible solar storm as the cause.

PHOTO: GOLDPAIN PHOTOGRAPHY





MegaPixel

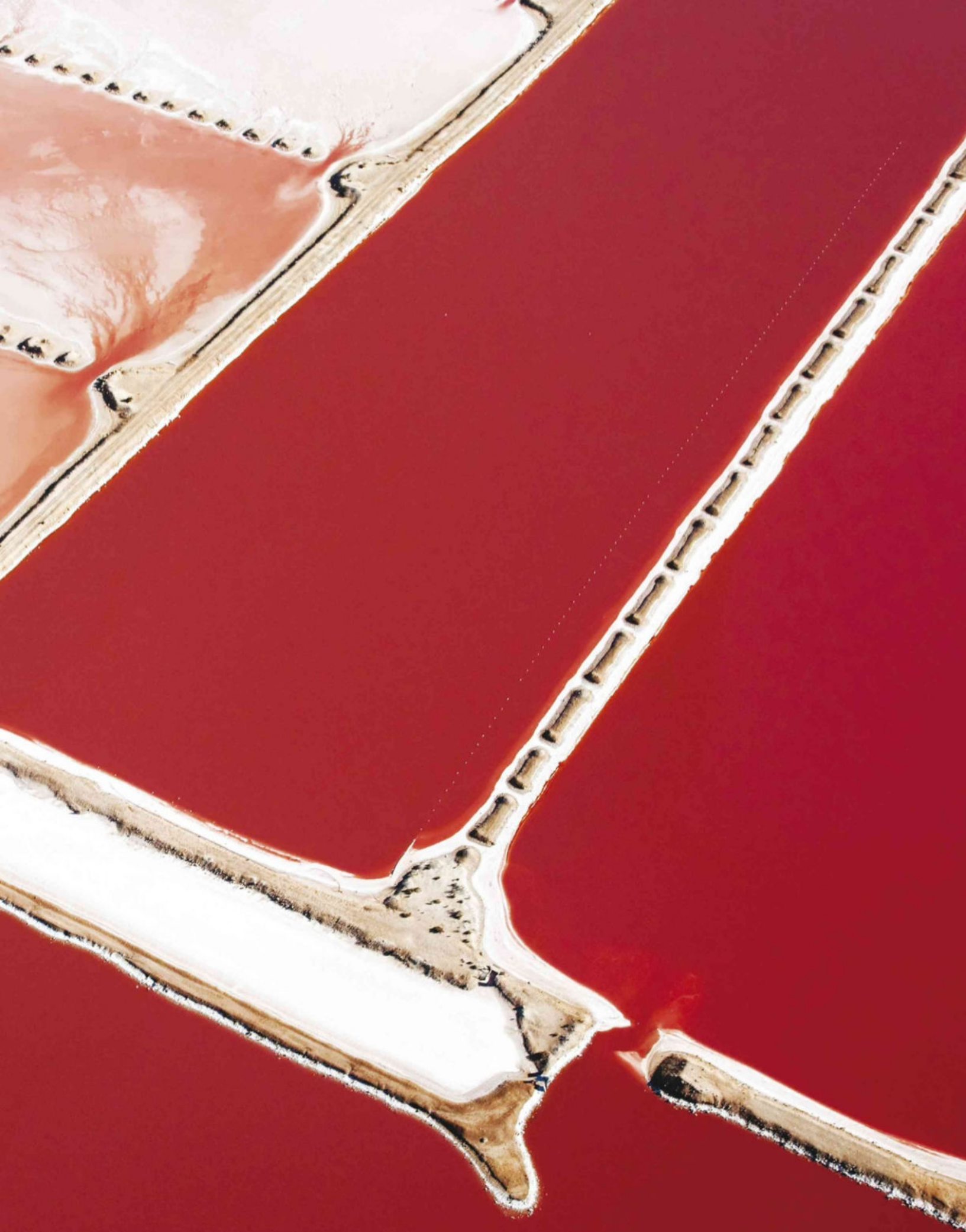
Red, red brine

THIS SALT LAGOON, resembling a painting by Mark Rothko, is the biggest algae farm in the world. Located by the coast in Western Australia, it contains the single-celled *Dunaliella salina*. These usually appear green, but under the bright Australian sunlight they begin to produce beta-carotene – a pigment that gives pumpkins and carrots their orange colour. It's farmed for use in both food colourings and medicines.

"It is a photo-protectant", says Alison Smith, Professor of Plant Biochemistry at Cambridge University. This means the algae form the pigment in direct response to the incident light, in order to protect themselves against damage from the Sun's harmful ultraviolet rays. "The algae are grown up to high density in one place and then flooded into the shallow open ponds," explains Prof Smith. "As the water evaporates, the salt concentration increases, and this exacerbates the response."

The farm is made up of a network of connecting lakes that are fed from the salty Indian Ocean, in order to encourage production of beta-carotene.

PHOTO: STEVE BACK





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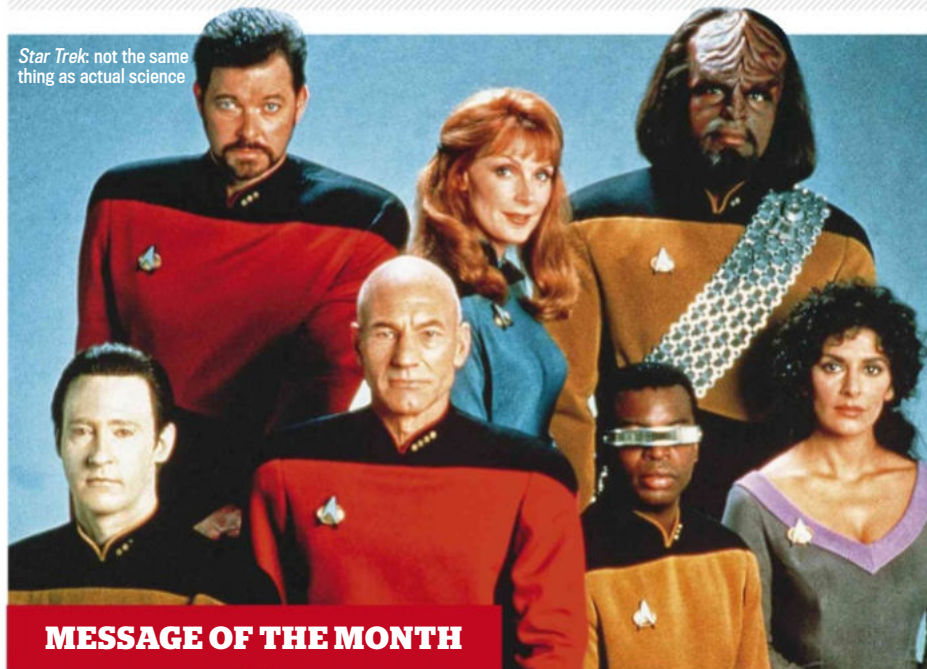
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Star Trek: not the same thing as actual science



MESSAGE OF THE MONTH

Star Trek's alien life

Your columnist Stephen Baxter reports on the paper by Kazakh scientists Vladimir shCherbak and Maxim Makukov concerning the possibility that a message could have been artificially implanted within our DNA long ago by an alien civilisation (October, p114). Baxter describes this as a 'new claim'; however, a very similar claim was made 20 years ago!

In the *Star Trek: The Next Generation* episode *The Chase*, first aired in 1993, teams of Humans, Vulcans, Klingons, Cardassians and Romulans come together following research showing that certain DNA sequences from these humanoid species, when assembled, form a computer program delivering a message of peace and goodwill from the progenitor species.

This species is supposed to have lived four billion years ago and seeded many 'Class M' planets with genetic material, from which the various humanoid species evolved. So I would suggest that perhaps the Kazakh scientists should share the credit for this idea with Ronald D Moore and Joe Menosky who co-wrote the episode... or did they actually get the idea from *TNG*?

Mark Wiggin

Fascinating, as Spock might say. Of course a scientific claim made in a published paper is rather different from an idea in a fictional story. But hats off to the Star Trek writers for coming up with such an imaginative idea. – Ed

Write in and win!

The writer of next issue's Message of the Month wins a Jabra Solemate portable Bluetooth speaker, worth £99.99. You can play music wirelessly via Bluetooth from phones, tablets, laptops and mp3 players, or connect it using a 3.5mm audio cable or USB lead. www.jabra.com



Perchance to dream

I was interested in the article on sleep by Dr Penelope Lewis (September, p34). We all dream when in deep sleep, but when I awake and open my eyes, and close them again after a few seconds, I see images in my right eyelid. It's like a small TV screen in full colour and detail – sometimes still pictures and occasionally moving. They only last for a few seconds and then disappear into a dot. Strangely they are mostly of well-known people, and sometimes country views.

What is happening and have any of your readers experienced anything similar?

Maurice Raynor, Hampshire



Cats: best kept off white rugs, say the experts

Cats: paws for thought

I was fascinated by BBC TV's *The Secret Life Of The Cat*, and equally so by Dr John Bradshaw's article in the September issue of *Focus*. In the 1960s, we had an open coal fire in the living room, which was a magnet for our female tabby Sheba, who established her place on the white hearth rug. Cat hair on a white hearth rug is not good, so she was regularly shooed off, but eventually claimed another spot within range of the heat. When we recarpeted the living room with a deep shag-pile carpet, it totally freaked-out poor Sheba. She froze, transfixed as she was met at the door with what seemed to her to be a total 'no-go' area. Her discomfiture was short-lived as the white hearth-rug had become redundant, so she speedily reclaimed her original spot near the fire.

John Thexton

The problem with politics

In reminding us how ministerial decisions are influenced more by media reaction than by hard evidence, Robert Matthews

(October, p31) has put his finger on the central weakness of modern democracy – which is (put simply) that we have to be governed by politicians. The system effectively restricts membership of the government to a relatively small class of people who happen to possess good debating and media skills, and thus excludes a whole host of more able and better-qualified people from any real influence in governmental decision-making.

One answer might be to remove the (relatively recent) constitutional tradition that only Members of Parliament can be ministers or Cabinet members.

Stephen Trahair, Plymouth

Not-so-smart phone

When glancing at the cover of issue 257 (Summer) of *Focus*, I was excited to see top-of-the-range cameras pitted against a smartphone. I thought it was an interesting concept, but you seemed to neglect the fact that 'smartphone' is no longer synonymous with iPhone.

Surely you should have at least looked at the Samsung Galaxy S4 or (especially) Nokia's Lumia 1020. The Lumia's massive sensor and incredible megapixel count (41!), allowing almost lossless zoom and effortless reframing, should have caught your eye.

Joseph Owen

The Lumia wasn't available at the time we tested the cameras and we chose the iPhone only because its camera is pretty representative of the pixel count on most current smartphones. – Ed

Linear collider views

Regarding the article in the September issue (p56) about scientists at CERN wanting a bigger accelerator than the one they already have, just how big do they need to go?

In the March 2011 issue there was an article by Robert Matthews, who always displays a healthy scepticism regarding some aspects of scientific research, remarking that to go on probing further will eventually require an accelerator larger than the Galaxy. Governments may soon begin to balk at the growing cost because the results obtained from the present LHC, and presumably those from any subsequent larger version, seem to be of interest to no-one but a clique of particle physicists.

David Storer, Totton

I found the article on the International Linear Collider very interesting. I always assumed that a successor to the LHC would simply be a larger version, generating even higher particle velocities and perhaps even constructed in space. I would have thought that building the ILC in Japan would not be advisable due to that country's history of seismic activity.

Ron Johnson, Harlow, Essex

Capturing bubbles

I recently experimented with soap bubble photography and, among many others, I



Martin Smith captured this great shot of a soap bubble

captured a shot that shows the split second in time when a water drop hits a soap bubble. Surprisingly the bubble did not burst. Instead, the resistance of the bubble slowed down the drop so that it split and elongated, leaving a tear drop inside and a water drop outside. It's a pretty cool illustration of the effects of bubbles and water and surface tension.

Martin Smith, Stambolovo, Bulgaria

A mag to get your teeth into

I stumbled upon your magazine in my dental surgery. Having not done particularly well in science at school, I was hoping that the nurse would call me through as soon as I picked it up. How pleased I was when a couple of minutes turned into a good 20 and I was able to get my teeth stuck into it! All the articles were well written and simple to understand. I am now in the comfort of my own living room reading your next issue, without the dreaded drill buzzing next to me. Thank you for doing what my teachers promised all those years ago.

Russell McSweeney, Oxford

There you have it – conclusive proof that reading Focus is better than having your teeth drilled. – Ed

Oops!

- The Universe grew by a factor of 10^{60} and not 1,060 as we printed on p38 of October's issue. The caption on p41 was also incorrect: the first galaxies formed a few hundred million years after the Big Bang.

- On p19 of the September issue, the 'core drilled down' label should have read 3.623km.

- In August (p58), the phrase 'micturition syncope' was misspelt.

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SCIENCE AND TECHNOLOGY

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DISCOVERIES

News and views from the world of science

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NEW LOOK FOR NOAH'S ARK

How to save endangered species and transport them to other planets.

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PUBLIC SPACE FLIGHTS SOON

Virgin Galactic's SpaceShipTwo all set for commercial flight in 2014.

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EXAMINING THE ELEPHANT MAN

New tests aim to confirm the cause of Joseph Merrick's famous deformities.

THE BIG STORY

Did life on Earth begin on Mars?

A cocktail of chemicals on the Red Planet could have given life a kick-start before it seeded Earth

HOW DID LIFE begin? And, perhaps more intriguingly, where? Biochemists have proposed various locations, from tepid 'primordial soup' ponds on Earth's surface to 400°C hydrothermal vents on the ocean floor. But now a controversial new proposal suggests life began on Mars before travelling to the Earth via a meteorite.

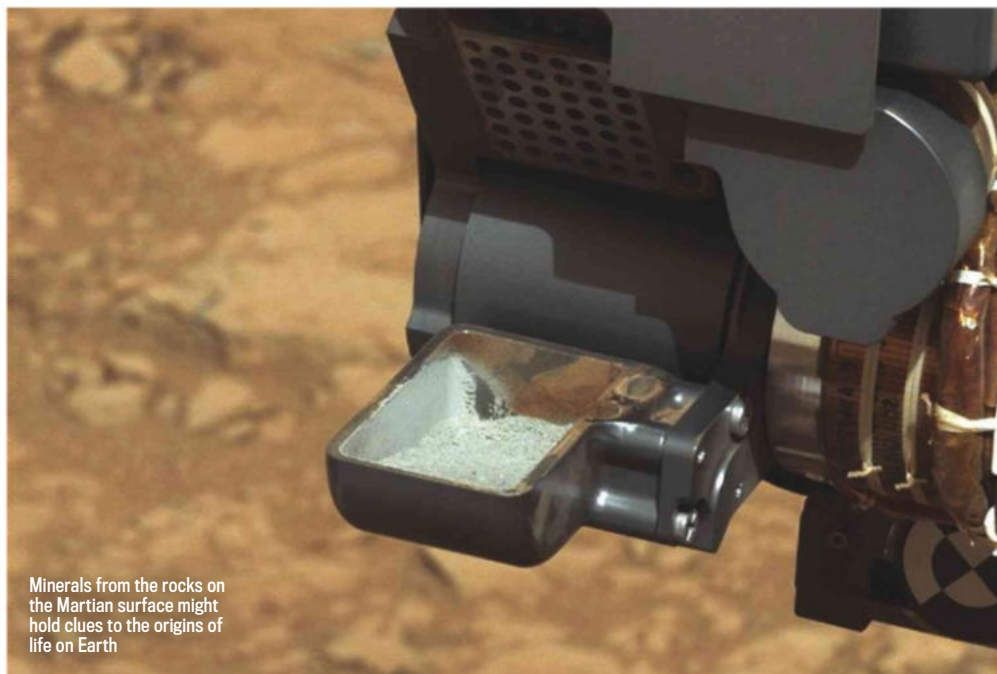
Dubbed 'panspermia', the theory that life can travel across the Universe and seed other planets is not new. But Dr Steven Benner of the Foundation for Applied Molecular Evolution says there is a chemical mechanism that proves the theory. "People have tended to reject

panspermia because it doesn't solve the problem of how life originated – it just moves the problem," says Dr Benner. "But what has come out of this entire discussion is serious lab work – researchers producing clearly defined chemistry that give you bits and pieces of the puzzle."

RNA, a molecular messenger that shuttles information between DNA and proteins, can be produced by a combination of minerals called borate and molybdenum in the presence of high oxygen levels. Early Earth, says Dr Benner, lacked the high oxygen

Dr Steven Benner's work could lend more weight to the panspermia explanation of the origins of life





Minerals from the rocks on the Martian surface might hold clues to the origins of life on Earth

➔ levels that would have stabilised these mineral forms, and the watery nature of our planet would have broken apart the embryonic RNA. But Mars, being dry and highly oxygenated, would have been the perfect environment.

Dr Benner's idea builds on the 'RNA world' concept, which suggests that RNA could have been the precursor to early forms of self-replicating and mutating life.

"Prebiotic chemists need borates to prove their 'RNA world' hypothesis because they prevent RNA-precursor molecules from simply turning into tar," says geologist Dr Robert Hazen of the Carnegie Institution for Science, who invited Dr Benner to present his idea at August's Goldsmith Conference in Italy. "At this very moment, NASA's Curiosity rover is probing the surface of Mars. If we find signs of borates or molybdenates, it will affect our thinking about life on other planets. Even if we're not 'all Martians', Mars has a great story to tell us how life could evolve elsewhere."

A related study from Christopher Adcock and Elisabeth Hausrath at the University of Nevada has suggested another tantalising

reason why life could have arisen on the Red Planet. Their lab studies have shown that phosphates, essential to the building blocks of both DNA and RNA, are weathered away from the minerals found in rocks on Mars 45 times faster than they are on Earth. Moreover, data from the Opportunity and Spirit rovers indicates that levels of phosphate on Mars are five to 10 times higher than on Earth. However, if their work suggests a Martian origin for life, it would require the Red Planet to have been wet, not dry.

Are the two studies incompatible? Dr Adcock doesn't think so. "I think it's too soon to tell if our study conflicts with Dr Benner's," he says. The reason being it's possible that alternating cycles of wet and dry of now-dead Martian weather provided the right conditions.

The ultimate next step, however, is the creation of life from scratch in the lab. "If you can do that in the lab, in conditions that could have existed on early Earth or Mars," says Dr Benner, "then you have a solution for the question of the origin of life. And I think we'll see that in the next year or two."

Zoe Cormier

ANALYSIS

Nick Lane



Biochemist at UCL and author of *Life Ascending*

“ DR BENNER IS a good chemist, but this is wishful thinking. The idea of the 'primordial soup' just doesn't work in terms of thermodynamics, and he's trying to save this unworkable model by transplanting it somewhere else.

Dr Benner argues that borates help to stabilise RNA, but it's a philosophical fallacy to say that because something helps, it's therefore necessary. Boron may be good for pre-biotic chemistry, but modern cells do all the same RNA-producing chemistry without it. Molybdenum, meanwhile, is one of the most common minerals in interstellar dust, so it's hard to imagine this isn't happening on other planets.

I'm not saying this isn't a credible model for how life could have arisen on Mars – it would be surprising if life hadn't arisen on Mars – and I'm sure panspermia is possible. But it doesn't solve the ultimate problem. If bacteria are travelling through space, that's fine, but I doubt it's required for life to start on Earth. I think life arose on hydrothermal vents in the deep oceans, where the shopping list for life consists of rocks, water, carbon dioxide and hydrogen.

Whatever the answer, this is all part of the human urge to explore frontiers, and the origin of life is one of them. We are tantalisingly close to testing out the ultimate question in the lab – anyone with an ounce of curiosity will want to know the answer. ”

WHAT DO YOU THINK?

Could life on Earth have originated on Mars, or perhaps even further afield? Let us know your thoughts at facebook.com/sciencefocus



TIMELINE

How the theory of our off-world origin developed

1903

Swedish chemist Svante Arrhenius, building on the work of ancient Greek philosophers from the fifth century, hypothesizes that life could have first arrived on Earth via a meteor.

1953

Stanley Miller and Harold Urey produce amino acids – the building blocks of life – by sparking a mixture of methane, hydrogen, water and ammonia with electricity.

1986

Walter Gilbert outlines the mature 'RNA world' concept: that early life began with a soup of RNA molecules that could self-replicate, mutate and evolve.

1996

Scientists claim that a Martian meteorite, found in Antarctica, contains fossilised 'nanobacteria'. Later studies refute their claims; existence of life on Mars remains unproven.



2011

Philipp Holliger synthesizes an RNA enzyme, tC19Z, that is capable of replicating itself – lending credence to the idea that RNA alone could provide the building blocks for life.

2013

Steven Benner illustrates a chemical model for how borate and molybdenum minerals could have combined in Mars's atmosphere to produce RNA and thus life on Earth.



One and some: the ability to distinguish between quantities is now believed to be hard-wired into our brains

Neuroscience

Quantity surveying an innate skill

THE KEY TO being good at maths could lie in two small strips of tissue on the surface of your brain, just above and behind your ears. A new study shows that these areas in the posterior parietal cortex are laid out so that the sight of different quantities of things fires up neurones in different places.

The findings of the study suggest that our ability to distinguish quantities is built in, like our senses of sight, sound and smell. It is the first evidence of a cortical 'number map' in the human brain.

Cortical maps are specific areas of the brain that function in a way that corresponds to particular sensory stimuli. The visual cortex, for example, reflects observed images like a mirror, with adjacent portions of the visual field exciting adjacent neurones. Similarly, a touch on your upper arm triggers activity in the neurones lying next to those that respond to a touch on the

elbow. The ability to discriminate quantities, or 'numerosity', however, is the only faculty other than the five senses that has been found to map onto the cortex in this way.

The study, led by Dr Benjamin Harvey of Utrecht University in the Netherlands, showed eight human volunteers pictures of differing numbers of dots while scanning their brains with a functional magnetic resonance imager. The researchers found that neurones on the inner edge of the quantity-processing strips responded to smaller quantities, while those on the outer edges fired in response to larger numbers.

They also found that inner neurones responded to specific quantities, while outer ones only reacted to big numbers. This is almost certainly why we tend to get vaguer as numbers get bigger, counting 1, 2, 3, 4... a dozen, many, hundreds and so on.

RITA CARTER

1 MINUTE EXPERT Pacific Decadal Oscillation

What's that?

It's a naturally occurring cycle that has a cooling effect on the Pacific Ocean's waters.

Why is it important?

According to a study published in the journal *Nature*, the cooling caused by the Pacific Decadal Oscillation (PDO) could counter the warming effects of increased levels of atmospheric carbon dioxide. This, say the study's authors, could explain why average global temperatures since 1998 have failed to rise in accordance with predictions.

How did they work that out?

A team led by Prof Shang-Ping Xie at the Scripps Institution of Oceanography developed a climate model that took into account the greenhouse effect and the effect of ocean surface temperatures. "Only when we input equatorial Pacific Ocean temperatures into our model were we able to reproduce the flattening of the temperature record," Prof Xie told the BBC.

How long does it last?

The PDO sees average water temperatures rising and falling over a 20-30 year period. Since 1999 we've been in its cool phase; its last warm phase lasted from 1977-1999.

WHO'S IN THE NEWS?

Carlos Ghosn

Chairman and CEO of Renault and Nissan

What did he say?

He announced plans, in August, for a new line of self-driving cars powered by Nissan technology called Autonomous Drive, which he says will be available by 2020.

How likely is that to happen, though?

Quite likely, actually, given Ghosn's track record. In 2007

he said Nissan would have a mass-market, zero-emission vehicle on the roads by 2010; in 2010 Nissan launched the Leaf, now the world's best-selling electric car.

Isn't Google doing something similar?

Yes, but Google has yet to set a release date. However, unlike Google's proposed

autonomous cars, Nissan's won't require an internet connection to navigate, just GPS and a load of sensors.

What advantages would driverless cars have?

They'll make drink driving and parallel parking a thing of the past. Plus you'll be able to catch up with the latest issue of *Focus* on your journey.

PATENTLY OBVIOUS with James Lloyd Inventions and discoveries that will change the world



Go go gadget gloves!

LOOKING LIKE SOMETHING from the sci-fi film *Minority Report*, Samsung has invented some nifty robotic gloves capable of teaching you complex hand gestures such as sign language.

The patent application describes how the robo-gloves will manipulate the wearer's hands into various shapes. Someone learning sign language first selects a word, and then motors in the glove's finger joints will manoeuvre their hand into the correct position. The gloves might even include voice recognition technology so they can 'hear' the wearer's words and automatically convert them into sign language gestures.

Although the patent focuses on sign language, the possibilities don't end there. Boxers or golfers might wear the gloves to perfect their swings, while a piano student could don a pair to learn a new concerto. Or how about a robotic version of paper-scissors-stone?

Patent number: US 20130204435

Camera phones go 3D

FANCY TAKING 3D photos of your loved ones? Google is patenting a technology that'll let you take 3D snaps with a regular smartphone. Taking a 3D pic usually requires two lenses to capture images from different angles. Google's system snaps an image, then provides instructions on where to position your phone for a second shot. Similar apps exist, but Google will automate the picture-taking process by tracking the position of your phone as you move it.

Patent application number: US 20130201301

Organised chaos on the dancefloor

DANCEFLOORS AT SILENT discos – where clubbers wear headphones so they can bop along to their own tunes – could be about to get a lot less chaotic. Apple has patented technology that wirelessly sends the tempo of a master track to each dancer's smartphone or mp3 player. The gadget then picks a track from the clubber's library with a similar tempo, so that all of the participants boogie in unison to their own music.

Patent application number: US 8521316

Conservation

Building a new ark

Japanese researchers are creating an ark to house genetic information from “all the species in the world”, according to the project's leader Dr Takehito Kaneko of Kyoto University. Dr Kaneko hopes the ‘ark’ will not only help save endangered species but, if necessary, transplant them to other planets.

Preservation methods that set out to store the animals' genetic information typically do so either by freezing eggs and sperm samples or storing their genetic code in computers. But Dr Kaneko's method involves treating sperm samples with a protective solution, before freeze-drying them. The samples can then be stored at 4°C, which is cheaper and uses less energy than storing frozen samples in sub-zero temperatures.

Female rats and mice have been artificially inseminated with sperm preserved for five years using Dr Kaneko's method, and they have given birth to healthy pups.

The newest additions to Dr Kaneko's ark are the frozen

sperm of the Sunda slow loris, chimps and giraffes. Next, he hopes to develop techniques to store female eggs, which are bigger and harder to preserve.

Dr Rhiannon Lloyd, a research fellow in the Cellular And Molecular Neuro-Oncology Group at Portsmouth University, says Dr Kaneko's technique is an achievement but it will be the eggs that determine the prospects for this idea. “You need both sides of the coin, and obtaining eggs from large mammals, such as rhinos or elephants, is very difficult. Their reproductive tracts are huge and they have thick, sensitive skin. You also need to make sure the habitat is there to support them.”

Dr Kaneko acknowledges that conserving the animals' habitats is important but points out that we don't know what conditions will be like in the future. “If we have to move to another planet, we could take Earth species with us by freeze-drying them – it's the ultimate new preservation method.”

What good is moving to another planet if you can't take a slow loris with you?



GTi IS BACK



PEUGEOT RECOMMENDS TOTAL Official Fuel Consumption in mpg (l/100km) and CO₂ emissions (g/km) for the 208 GTi are: Urban 34.4 (8.2), Extra Urban 60.1 (4.7), Combined 47.9 (5.9) and CO₂ 139 (g/km).

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MOTION & EMOTION



PEUGEOT

Space

SpaceShipTwo flexes its wings

SEEN HERE IS Virgin Galactic's SpaceShipTwo making its second supersonic flight on 5 September. The craft is on course to be the first to take commercial passengers to the edge of space. The test flight also saw the space plane successfully deploy its shuttlecock-inspired 'feather' braking system for the first time.

For this test flight, SpaceShipTwo was carried

to a height of 46,000ft (14,000m) above California's Mojave Desert by its carrier plane WhiteKnightTwo before it was launched. After a 20-second rocket burn, SpaceShipTwo reached a speed of just over Mach 1.4 and an altitude of 69,000ft (21,000m).

The space plane then used its 'feather' braking system that rotates the vehicle's wing and tail sections upwards to generate wind resistance

and slow it down in order to enable a smooth descent.

In a video of the event posted on YouTube, Sir Richard Branson called the flight "another major milestone" and said, "We are on track for a 2014 start of service."

Russell Deeks

SpaceShipTwo got one step closer to going into full service after its September test flight



HOT TOPIC

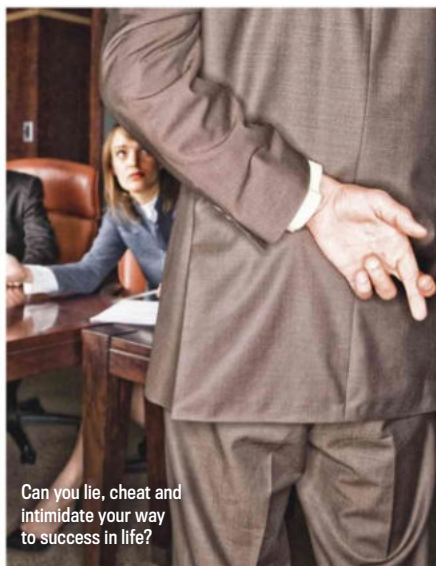
Do cheats and bullies prosper?

THEY SAY VIRTUE is its own reward, but are the rewards for being a bully or a cheat even greater? Two new studies suggest that maybe nice guys and girls do finish last.

In the first study, published in the *Journal Of Personality And Social Psychology*, a team led by Nicole E Reudy at the University of Washington found that a person who behaves unethically experiences a 'cheater's high' afterwards. This finding was based upon research where participants engaged in a number of tests in which the possibility of cheating was readily apparent, then completed a questionnaire about how they felt afterwards. Those who cheated felt, on average, better than those who completed the tests honestly.

In the second study, conducted by researchers at the University of Warwick and Duke University Medical Center, a group of 1,420 participants had their

behaviour monitored and assessed between the ages of 9 and 16, and then reassessed from 24 to 26. Those who had been bullied when young were more likely to have drink, drug and health problems in adult life, to have poor qualifications and work records, and to be on low incomes. Those who had been bullies, on the other hand, were generally healthier and wealthier – though victims of bullying who had gone on to become bullies had the worst outcomes of all.



Can you lie, cheat and intimidate your way to success in life?



WHAT DO YOU THINK?

Let us know your opinions at facebook.com/sciencefocus and our forum at sciencefocus.com/forum



Greg Gillies: *I believe evolution favours two traits – strength and intelligence. Ultimately the intelligent people win as they can outsmart bullies. But that does put the bullies in a favourable position ahead of the weak, sick and stupid. It's likely that school bullies' position of dominance at a young age helps build their confidence, which benefits them in later life. Incidentally, I'm not a bully and never have been.*



Kathryn Weir: *I think being a bully will lead people to do what you want but only because they fear you. In the long term, if the bully ever needs help or support they won't get a lot from people around them because of the way they treated them in the past.*



John Feather: *Sometimes being a nice guy gets you nowhere, but I'd rather be a nice guy and nowhere, than somewhere and a bully.*



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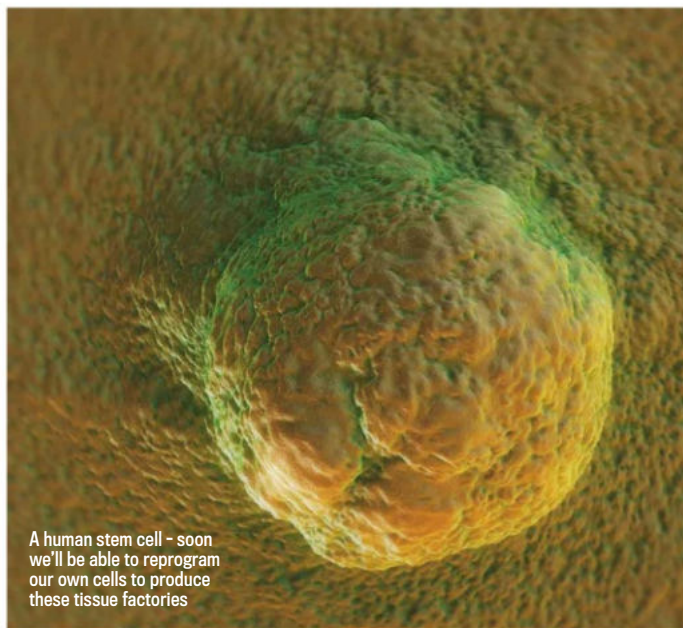
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A human stem cell - soon we'll be able to reprogram our own cells to produce these tissue factories

Cytology

Cure yourself with your own cells

PATIENTS COULD ONE day be treated with reprogrammed cells grown in their own bodies. Scientists have taken a step towards this treatment by reprogramming cells in mice to produce stem cells. These have the potential to become almost any type of cell – similar to cells in embryos a few days old.

Researchers working on regenerative medicines are interested in embryonic stem cells because their fate is not yet decided – they could develop into skin, heart or any other type of cell. But using cells from embryos to treat other people is controversial and risky. The cells could be rejected as they don't come from the patient's own body. So instead, scientists have been using revolutionary techniques to reprogram adult cells in the lab to produce those needed to repair damaged tissues.

In July this year, Japanese researchers got the go-ahead to start the first clinical trials using reprogrammed human skin cells. The scientists will use them to create eye cells to treat

macular degeneration, which causes progressive sight loss.

While cells like those in the Japanese trial are reprogrammed in a petri dish, Manuel Serrano's team at the Spanish National Cancer Research Centre in Madrid has focused on creating more adaptable cells by producing them in living animals.

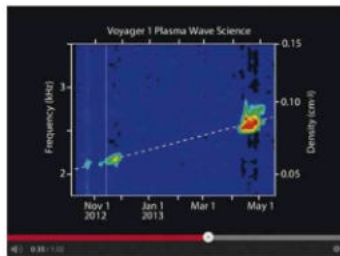
Serrano's team infected mice with viruses carrying carefully assembled DNA sequences. These encourage cells in some of the animals' organs, such as the kidneys, to reset their internal clocks to an earlier stage of development. "They were closer to real embryonic stem cells. Actually, they were more primitive than embryonic stem cells," says Serrano.

Although the study suggests adult cells are more adaptable than scientists once thought, the challenge now is to find a shortcut between one cell type and another. The mice in Serrano's study also developed tumours, so scientists have to figure out ways to reset cells in humans without making us sick.

HAYLEY BIRCH



CLICK HERE with Kelly Oakes
New websites, blogs and podcasts



beyond the influence of the Sun's magnetic field last year. NASA recently released this recording of what it heard.

VOYAGER'S SOUNDS OF INTERSTELLAR SPACE

[youtube.com/watch?v=LIaZWb9_si4](https://www.youtube.com/watch?v=LIaZWb9_si4)

You might not be able to hear someone scream in space, but it isn't silent. The Voyager spacecraft launched in 1977 and finally reached a region

PROJECT QUICKSILVER

<http://forecast.io/quicksilver>

This is a real-time map of global temperatures. You can zoom out to get an overview of the whole world, or zoom in to specific countries if you want more detailed information. It also enables you to rewind through history

so you can go back and download high-resolution images of the world's temperature patterns at specific points in time.

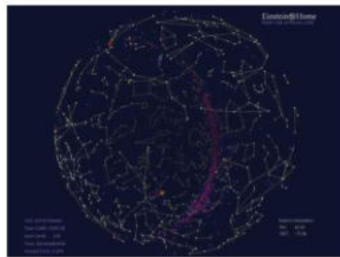


3D FOSSILS

www.3d-fossils.ac.uk

If you've ever picked up a fossil on the beach and not known what it was, this site will be a great addition to your bookmarks. Type in the suspected name or time period of your find and it'll bring up a high-resolution, 3D

image of any specimen in the British Geological Survey's archived collection so you can see how your fossil compares.



EINSTEIN@HOME

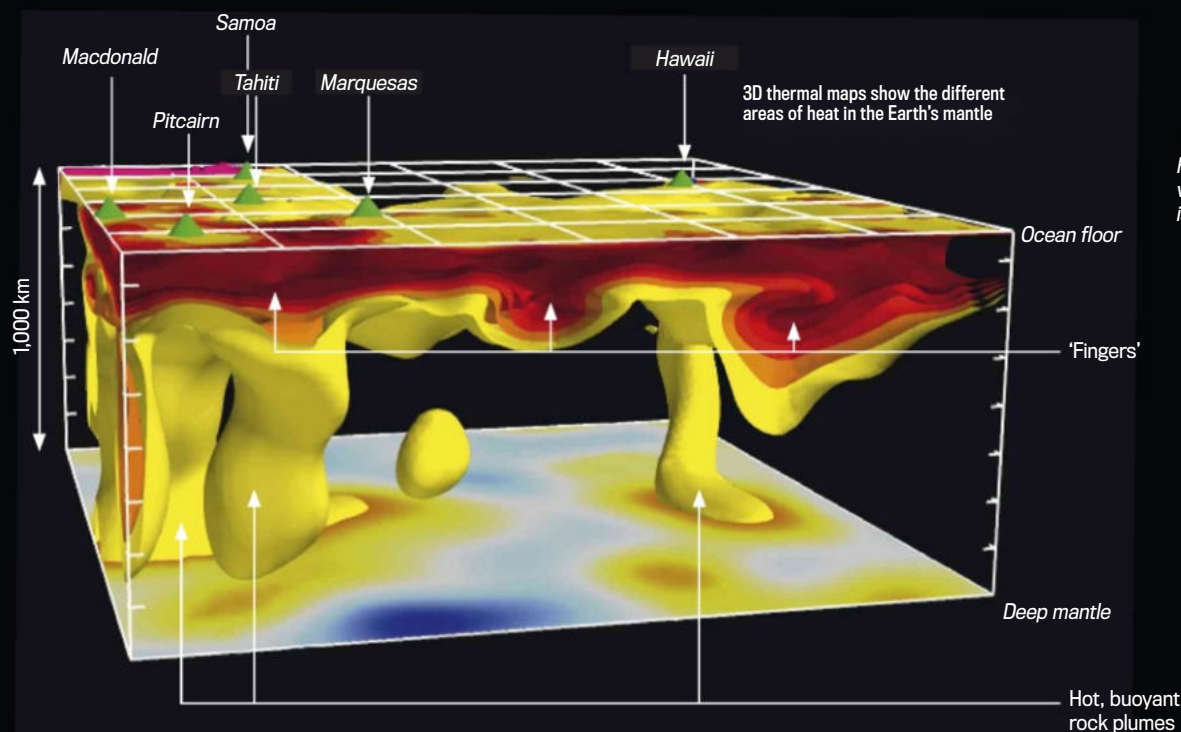
<http://einstein.phys.uwm.edu>

Fancy being the first person to discover gravitational waves? With Einstein@Home, you could be. Launched eight years ago, this long-running citizen science project is still making waves. Its volunteers have recently discovered 24 new dense, spinning stars, known as pulsars. But the project's ultimate goal – to find gravitational waves – has yet to be achieved.



KELLY OAKES is a science journalist who tweets from @kahoakes

Seismic waves created Pacific islands



IF YOU THINK this picture looks like a lava lamp, you're not that far off. It's actually a computer model that illustrates new findings about the conduction of heat within the Earth's mantle – findings that may shed new light on the formation of 'hotspot' volcanoes.

Many volcanoes occur where two of Earth's tectonic plates meet and can be explained by the movement of those plates. But hotspot volcanoes – such as those that formed the islands of Hawaii, Tahiti and

Samoa – sit a long way from such tectonic boundaries. For some time, geologists have suggested that plumes of heat within the mantle (seen here in yellow) were responsible for hotspot volcanoes. Now fresh evidence suggests a slightly more complicated explanation for their creation.

Using a process called seismic topography, which tracks the progress of seismic waves through the Earth, a team led by Scott French at the University of California, Berkeley has

demonstrated the existence of slow-moving waves in channels called 'fingers'. These occur at depths of 195–320km (120–200 miles) below the surface of the ocean floor.

Since seismic waves slow down as temperature increases, these slower waves are thought to indicate areas of higher temperature, and French suggests that it is the interaction between these 'fingers' and the mantle plumes that leads to the formation of hotspot volcanoes.

Virology

Thousands of viruses believed to be at large

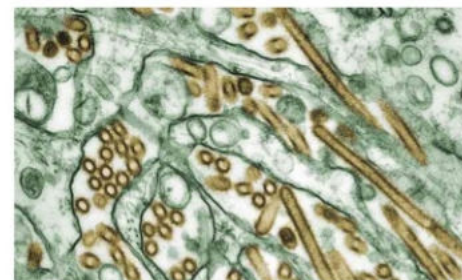
MAMMALS COULD BE harbouring more than 320,000 as-yet-undiscovered viruses, a new study suggests. It's believed the approximation could help in the search for new viruses and prevent future outbreaks.

"We have never successfully predicted an outbreak," says Dr Simon Anthony of Columbia University, part of the team that came up with the figure. "This could help us address the major concern: the unknown." Almost 70 per cent of viral pandemics, including SARS, bird flu and

HIV, originated in animals before spreading to humans.

Dr Anthony and his team arrived at the 320,000 figure after researching the diversity of viruses in flying fox bats in Bangladesh. They found over 50 new viruses in the bats and extrapolated from this to take into account the other 5,486 mammal species.

Figuring out the true number of viruses could cost \$6.3 billion over 10 years. "This might sound like a lot of money," says Peter Daszak, President of the EcoHealth Alliance,



There could be thousands of viruses like avian flu, pictured here, that we haven't discovered yet

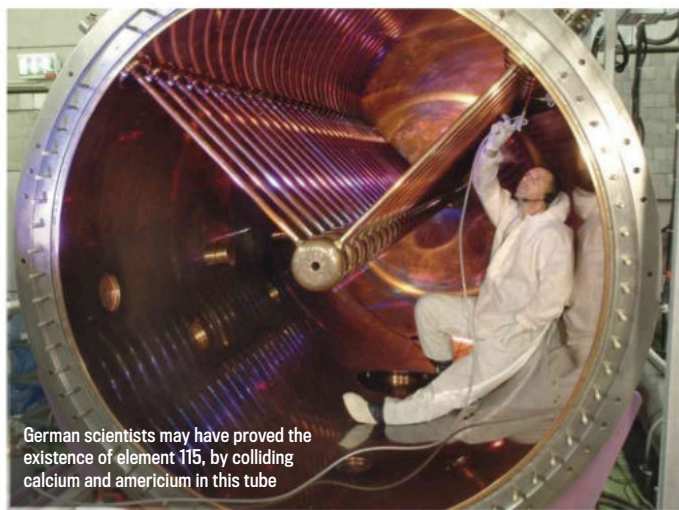
"but we're already spending huge amounts to prevent the spread and treat the symptoms of viruses like HIV."

"The ultimate goal is to discover the next HIV before it emerges," says Dr Anthony.

ZOE CORMIER

Chemistry

Element 115 glimpsed



German scientists may have proved the existence of element 115, by colliding calcium and americium in this tube

SCIENTISTS MIGHT finally have confirmed the existence of element 115. It doesn't occur naturally on Earth but can be created by colliding atoms.

Element 115 was first seen by Russian scientists in 2003, but at least one other independent sighting was needed before its existence could be confirmed. Now, researchers in Germany may have the extra evidence by creating

30 atoms of element 115. Each atom existed for only a fraction of a second, but their presence could be confirmed by detecting the elements produced as they decayed.

Chemists and physicists must now decide whether to acknowledge the discovery of the element – temporarily called ununpentium – or ask for further experiments.

James Lloyd

Meteorology

Was prehistoric big freeze caused by a meteoroid?

A DRAMATIC DROP in temperature that occurred around 13,000 years ago may have been caused by the impact of a space rock, says new research. The climate shift saw temperatures in the Earth's northern hemisphere drop by as much as 15°C, but scientists don't agree on what caused this big freeze, known as the 'Younger Dryas'.

One theory is that a meteoroid crashed into the Earth, sending up clouds of dust that chilled the planet – an idea that geochemists in the US now claim to have found evidence for. They studied

spherules – glassy droplets of molten rock – from the Younger Dryas period found in Pennsylvania and New Jersey. "The texture and mineralogy of these spherules tell us that they must have been created in a fireball following a violent impact," says Dr Mukul Sharma at Dartmouth College in New Hampshire, US.

The spherules have identical chemical signatures to rocks in Quebec, pointing to a possible location for the impact. But with no suitable impact crater found so far, many scientists remain sceptical.

James Lloyd



WHAT THE PAPERS SAY

Henry Gee on the latest from leading journals

THE SAME BUT DIFFERENT

DOES LIGHTNING EVER strike the same place twice? For evolution, at least, the answer is yes – and more often than you might think. A hot topic in evolution is 'convergence': the independent evolution of similar structures in unrelated species. Many kinds of bat, for example, have evolved echolocation, which allows them to build up a picture of their environment by emitting a series of high-frequency chirps and monitoring their echoes.

Evolving the ability to echolocate demands a whole slew of complex anatomical, physiological and neurological changes that drill right down to the genetic level. Because of this complexity, you'd think that echolocation would never evolve the same way twice, let alone thrice. But that's exactly what Joe Parker of the University of London and his colleagues have discovered. A scan of 2,326 genes in 22 species of mammals revealed signs of convergence in almost 200 genes associated with echolocation. This means that no matter how divergent the evolution of each case of echolocation, the function leaves its signature written at the genetic level.

But what's really amazing is that echolocation evolved in bats not once – which you'd expect, for such a complicated sensory system – but twice. And that's not all. Echolocation has also evolved in whales, such as the bottle-nosed dolphin. Echolocation is a smart way to get around in

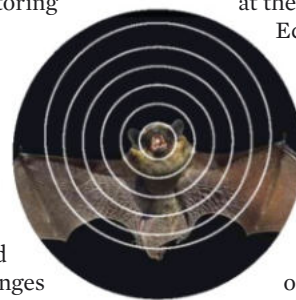
darkness, but you'd expect that it would have evolved in a completely different way in each lineage – the two bat lineages, and in whales. Looking at the particular structures involved, that seems to be the case at first. For example, the shapes of bats' ears and noses are highly divergent and look nothing like the structures that perform the same tasks in bottle-nosed dolphins.

But things are different at the genetic level.

Echolocating bats and dolphins tend to share similar mutations in genes involved in hearing and vision that aren't found in non-echolocating bats or other animals. For example, no fewer than

17 genes with an echolocation 'signature' found in bats and whales form a pathway of interactions centred around two genes involved in the development of the inner ear. Some of the genes might be connected with a shift in the way animals perceive the world, from sight to sound.

This work is the first systematic attempt to understand the relationship between convergence in outward form, and at the genetic level. We knew convergence in the natural world was rife but the fact that it's written so deeply in the genes is a revelation.



HENRY GEE is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

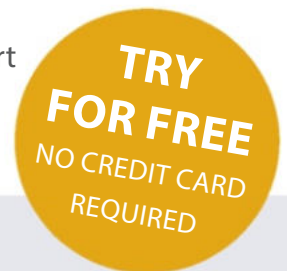
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Genetics

Elephant Man's mystery to be solved

Analysis of Joseph Merrick's DNA should confirm the cause of his deformities



to preserve the bones, which destroyed most of his DNA.

Now, however, scientists from Queen Mary University of London, the Natural History Museum and King's College London will use new DNA retrieval techniques to try and shed light on the mystery.

"The bones have been bleached and, we believe, waxed as well, which presents added difficulties for the extraction process," says Dr Michael Simpson of King's College London. "We use enzymes to remove the protein content and detergents to remove the lipid content, which should leave us with DNA. But because of the wax, there are additional compounds that need

to be removed so we need to tweak our extraction methods."

The team is currently fine-tuning its techniques but expects to start work on Merrick's skeleton within six months. Once they've extracted enough DNA to sequence, they will first examine it for evidence of Proteus syndrome. If they don't find it, they will go on to test for other conditions.

Russell Deeks

SCIENTISTS ARE TO re-examine the skeleton of Joseph Merrick, the severely deformed Victorian depicted in the 1980 film *The Elephant Man*.

The cause of Merrick's deformities has never been confirmed. Various conditions have been suggested, including the genetic disorders neurofibromatosis and Proteus syndrome. But finding a definitive diagnosis has proven difficult because Merrick's skeleton was bleached

Neurobiology

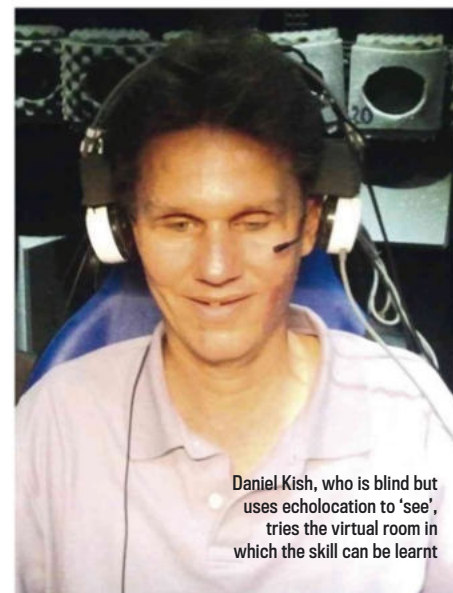
Train yourself to see with sound

IT'S NOT JUST bats and dolphins that can echolocate; humans can, too. A new study shows that we can be trained to use echoes to survey our surroundings.

Normally we filter out echoes of the noises we make to focus on the things we want to hear. But a virtual room developed at the Ludwig-Maximilians University in Munich enables people to be trained to reverse their echo suppression.

The virtual room's acoustics can be controlled to alter its dimensions and layout. Trainees listen to echoes of the sound they make to try to locate two virtual objects that are in the room with them. Professor Lutz Wiegerebe, the man behind the study, says echolocation was substantially improved with this training.

Hayley Birch



Daniel Kish, who is blind but uses echolocation to 'see', tries the virtual room in which the skill can be learnt

NEWS IN BRIEF

Clean hands, feeble mind

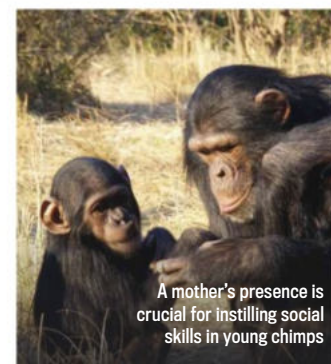
Research in 192 countries has shown there could be a link between greater sanitation and the prevalence of Alzheimer's disease. One potential explanation is that exposure to micro-organisms is important as it enables the body to develop a strong immune system. The team behind the research suggests that Alzheimer's might be linked to autoimmune disease.

Carbon dioxide rocks

The University of Newcastle, Australia is piloting technology that collects carbon dioxide and mineralises it to form bricks that could be used for construction. Instead of storing carbon dioxide in the ground, a process that is only practical in certain locations, this technology could be installed in any power station to reduce carbon emissions.

Mum's the word

Chimpanzee mothers play a key role in developing social skills in their offspring. Researchers from the Max Planck Institute for Psycholinguistics found that orphaned chimps played for less time and were more aggressive than those reared by their mother, suggesting that the secure environment a mother provides is important for socialisation.



A mother's presence is crucial for instilling social skills in young chimps



INSIDE SCIENCE

ROBERT MATTHEWS

The dream of fusion power remains, as ever, 30 years away

PHYSICS ISN'T A natural source of jokes – well, not unless you have a dodgy haircut and poor personal hygiene. And there's one old joke that has long since ceased to be funny: "Nuclear fusion power is 30 years in the future – and always will be". The quest to harness the power source of the stars, where hydrogen-like atoms are heated until their nuclei fuse together, releasing nuclear energy, was one of the first stories I covered in my journalistic career – which began over 30 years ago. Even then, I was giving a 'progress report' on a quest that started 30 years earlier.

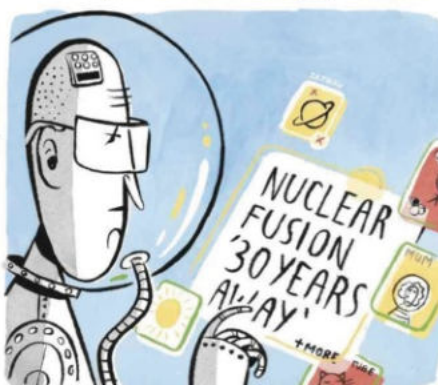
Now work is underway at the site of the world's biggest fusion machine, the International Thermonuclear Experimental Reactor (ITER), currently being built in Cadarache, France. Will this produce fusion-generated electricity? Er, no. Apparently, that's a job for yet another machine called DEMO, which may achieve this goal in – you guessed it – around 30 years.

So one of the reasons the joke isn't funny anymore is that it's turning into a statement of fact. But another is that in these days of austerity economics, politicians might use the joke as a reason for finally killing the quest for fusion. On the face of it, they'd be doing the right thing. Never in the history of tax-funded science has so much money been spent for so long in return for so little.

But that highlights one of the myths about nuclear fusion. For a start, it's not quite true that nuclear fusion power has never been generated. The first hydrogen bomb experiments on the Pacific island of Eniwetok showed the awesome

potential of nuclear fusion over 60 years ago – albeit in an uncontrolled way. Generating decent amounts of nuclear fusion safely took decades of further work. The current world record is held by the JET fusion machine near Oxford, which produced over 16 megawatts of power back in 1997. The bad news is that it could only be maintained for a couple of seconds, and even then needed 24 megawatts of power to sustain – not exactly ideal for a commercial energy source.

ITER is designed to achieve so-called break-even, where the reactions generate more power than they need to keep going. That doesn't sound a very ambitious target for a machine originally designed to achieve 'ignition', the nirvana of fusion power where the nuclear reactions are totally self-sustaining. It looks even more pathetic for a machine that was supposed to cost £2 billion, and could now top £20 billion.



“Never in the history of tax-funded science has so much money been spent for so long in return for so little”

But that highlights two more myths about fusion. First, commercially viable fusion power may work without ignition: just getting enough megawatts back out for every one put in may be good enough. The other misconception is that ITER is incredibly expensive. The hefty cost is being spread across all the European Union, plus various other countries, including the US, China and Russia. And even the most pessimistic estimates put total spending on ITER at around 0.5 per cent of the value of the world's energy market.

Even so, there's still a certain amount of discontent among politicians and even scientists, many of whom believe the fusion community have ridden the taxpayer's gravy-train for too long. It's hard not to agree, but I think the real problem lies in one final myth. The failure of fusion to deliver has prompted politicians to believe the best way forward is to give it less money but let deadlines slip. What they should be doing is the exact opposite: allocating much more funding, but with a much tighter deadline. It's a recipe that focuses minds and gets 'impossible' things done: witness, for example, the Manhattan Project, the Apollo Moon landings and the Human Genome project.

As things stand, fusion scientists are getting just enough funding to keep the '30 year' joke of endless energy alive. The time has come to give the scientists a big wad of money – and orders to give us the punch-line. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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EVERYDAY SCIENCE

HELEN CZERSKI

Your fridge magnet is a window into the quantum world

LAST WEEK, I bought myself a new toy: a collection of strong spherical magnets of different sizes. This week, I discovered that they've been tidying up when I wasn't looking. After a few days spent rattling around my travel bag, the clump of magnets has acquired a coating of loose change, mostly pennies. Pennies? Aren't they made of copper, and therefore not magnetic? I emptied my purse and had a bit of a play. The 20p and 50p coins don't stick. Ten pence pieces do, but not all of them. And one penny refused to be lured into the magnetic lair with its pals. What's going on?

Of course, the days of gold sovereigns and silver shillings that really are made of gold and silver are long gone. Today's coins are worth more as coins than they would be if you melted them down and sold the metal. But why would some 10p coins be magnetic and not others?

Magnetism is weird. You can make temporary magnetic fields by switching electrical currents on and off – that's what an electromagnet is. But a fridge magnet is a permanent magnet, and that's a bit different. It's a direct consequence of the rules of quantum mechanics, and the way that electrons behave. So maybe it's not so surprising that it's odd. Down there in the tiny weird quantum world, each electron can behave like a tiny magnet. If you can point lots of little quantum magnets in the same direction you get a big magnet. But it doesn't often happen. The quantum rules are strict, and the only common elements that can have their electrons lined up like this are iron, nickel and cobalt.

A permanent magnet is made of one of those metals and it has electrons that are permanently lined up. That's what's in a fridge magnet. As you bring it close to the iron in the steel fridge door, that permanent magnet mucks about with the electrons in the metal of the door. It turns them around, so that they line up. Then you've got lined-up mini-magnets in the door, and they attract your permanent fridge magnet. Every time you stick a shopping list to the fridge door, you're altering the quantum world. It only works because the fridge is made of atoms that allow their electrons to line up.

I'm writing this at a friend's house, and I think he thinks I've gone mad. I just emptied a jar of change all over the kitchen table, pinched a large



Discover quantum physics with some loose change and a magnet

“I love the idea that a handful of change carries clues to the quantum world, both about how mysterious it is and how useful it can be”

hedgehog magnet from the fridge and started sorting the coins by the year they were made. The only ones that stick to the magnet are 1p and 2p coins made after 1992 and 5p and 10p made after 2011. It turns out that until 1992, 'copper' coins were made from bronze, a mixture of copper and tin. No iron, nickel or cobalt, so old pennies aren't magnetic. But since 1992, pennies have been made of steel coated with copper. Steel is mostly iron, so that's why my magnet clump collected 1p and 2p pieces. The 5p and 10p coins were copper and nickel until 2012, but with very little nickel. They stay stubbornly on the table when I wave my hedgehog past. But the newer 5p and 10p pieces are made of nickel-plated steel, so... clink! They've joined the modern crowd.

We're used to the thought that the quantum world is there but somehow inaccessible. It's all happening somewhere far too tiny to worry about. But you and I can easily flip the quantum state of electrons in a 10p piece from 2013, something you can't do with one from 2011, even though the coins look identical. I love the idea that a handful of

change carries clues to the quantum world, both about how mysterious it is and how useful it can be. I think I'm going to carry magnets around with me everywhere from now on! ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter who appears regularly on *Dara O Briain's Science Club*

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THE FUTURE OF US

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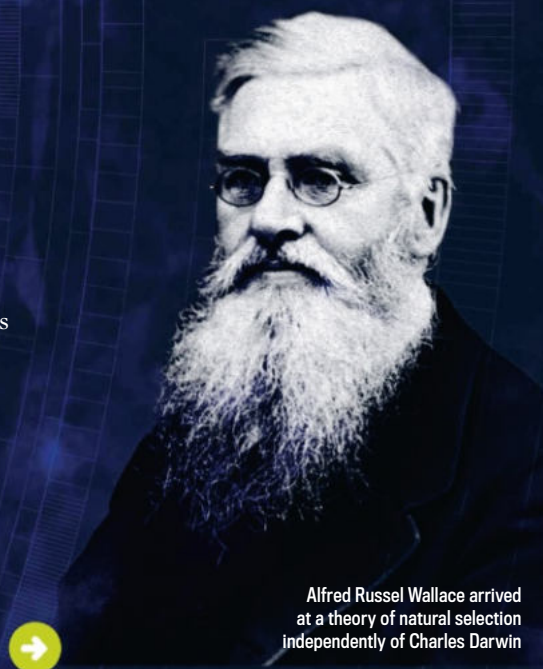


On the 100th anniversary of the death of the pioneering biologist Alfred Russel Wallace, new science is revealing that evolution is far from finished when it comes to human beings

Words: Hayley Birch
Illustration: Magic Torch

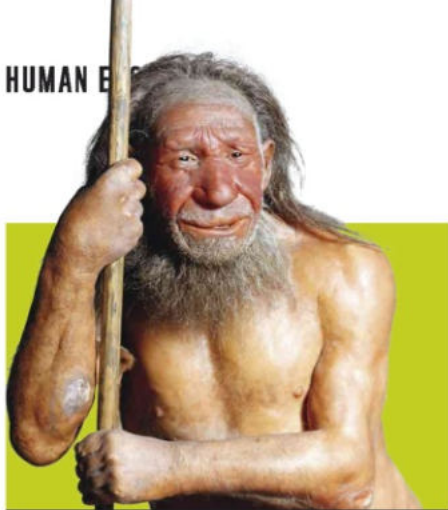
E VOLUTION. THE FOUR billion-year journey that brought us from the primordial pond to civilization, picking up brains, a backbone and opposable thumbs along the way. An unimaginably long, slow journey that ends right here. Or does it?

Isn't it possible that the theory Charles Darwin and Alfred Russel Wallace conceived of in the 19th Century – the theory of natural selection – applies to humans today in the same way that it did to the ancestors we share with chimpanzees? Could evolution be happening under our very noses? To us? The knowledge and technology we have amassed in our short existence puts us in the unique position of being able to contemplate our origins, and our future, as a species. But could knowledge and



Alfred Russel Wallace arrived at a theory of natural selection independently of Charles Darwin





We're more different from our ancient ancestors than they were from Neanderthals

ARE WE EVOLVING FASTER THAN EVER BEFORE?

Scientists aren't sure if we're still a work in progress and if we are, how rapidly we are changing

YES

1 Technology has changed our world beyond recognition. If evolution is a process that translates change in our surroundings into physical change, the rate of our evolution should be off the chart.

2 A study published in the *Proceedings of the National Academy Of Sciences* in 2007 suggests that we are more different from our ancestors who died 5,000 years ago than they were from the Neanderthals, who died out 30,000 years ago.

3 There are more of us than ever before. The number of random genetic mutations that are generated is huge.

NO

1 We're more mobile than ever before, so we make babies with people from other cultures. Compare this to the selective breeding of dogs – perpetuating wrinkly faces or sausage bodies requires in-breeding. What we're doing is the opposite.

2 Cultural adaptation has now become more important than genetic adaptation – we change because we learn from our parents, not because our genes change.

3 In the developed world, modern medicine keeps alive those who should not have survived under natural selection, perpetuating 'defective' genes. But it depends what you call evolution – simple changes in gene frequencies or survival of the fittest?

technology also be driving our evolution faster than ever before? "I think the rate of human evolution is faster than perhaps at any other time in the past," says Nick Bostrom, director of the Future of Humanity Institute at the University of Oxford.

GENETIC CLUES

It's not just idle speculation either. A 2007 study on the human genome shows our evolution sped up in the last 40,000 years (see left). Bostrom argues the current acceleration is because our environment is changing so rapidly. What Wallace realised in 1858 – and what Darwin had figured out a few years earlier – is that in a changing environment, those individuals that are better-suited to the new conditions flourish, while others fail. This is the basic principle of evolution by natural selection. Whether it's weather

patterns, disease, or diet, anything that changes in our natural or man-made environment is a potential pressure that could determine the course of our evolution.

We may think of evolution as something that happened to us in our distant past, while we were still working out how to make fire, but there are examples of genetic adaptations within the last 10,000 years – relatively recently in evolutionary terms. Take the genes that allow us to digest milk. Today, lactose intolerance is considered a condition, but until the advent of agriculture, it was the norm. As hunter gatherers turned to dairy-farming, being able to drink milk became a selective advantage. Those who had the favoured genes were provided with a good source of nutrition and energy, and had more healthy children.

Bostrom says this proves technology has already had an impact on our genes.



"Agriculture is a kind of technology," he says. "And I'm sure there are more subtle but pervasive influences throughout the human genome of having lived in civilisation for thousands of years." Maybe. But 10,000 years is a pretty long time ago. The big question is: are we still



"The rate of human evolution is faster than perhaps at any other time in the past"

Nick Bostrom, director of the Future of Humanity Institute at the University of Oxford



Ötzi the Iceman died around 5,300 years ago; scientists have found that he was lactose intolerant, being from a time and place where agriculture hadn't conditioned the body to digest milk

If ginger genes could somehow offer protection against a global pandemic, the future could be orange...

HOW WILL WE HAVE CHANGED 1,000 YEARS FROM NOW?

With technology and our knowledge of how the human genome works, we could speed up the pace of evolution with radical results

WE COULD BECOME SUPER-HUMAN

Disease-resistant: Genes that offer protection from big killers such as HIV and malaria. These genes would only spread without good vaccines or cures.

Super-intelligent: If we could work out the genetic basis of human intelligence,

we could start screening fertilised eggs to make brainier babies.

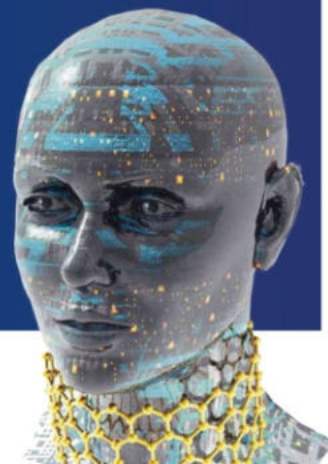
Ginger: What if genes for resistance to the next plague were associated with genes for red hair? Natural selection dictates that all the survivors would be ginger.

Better-looking: In countries with good support for single parents, it's a perfectly safe strategy to pick a mate with the best genes and forget about looking for a life partner. So why shouldn't mums just pick the best-looking dads?

MAN AND MACHINE MERGE

A life in silicon: If some futurists are right, then it could be possible to transfer human intellect to machines, by using detailed scans and models to produce a digital copy of a brain.

Obsolescence: Once we create artificial intelligence that's cleverer than us, who knows what could happen? Machine intelligence could mean that humans become obsolete.





HIV cells (green) open the door to infection via bacteria (background); pressures on the human body like this are forcing it to adapt over generations

ADAPTING TO THE SPACE AGE

If we want to conquer the final frontier we may have to make some changes

LET'S IMAGINE FOR a minute that humans had to adapt to low-gravity conditions in space. Earlier in 2013, the crew aboard the International Space Station explained how the body adapts in the short-term. Balance and co-ordination takes a while to re-adjust and astronauts' legs get thinner – mainly because gravity is not pulling fluid down into the lower regions of the body. Over time, space travellers can lose some of their bone strength and muscle mass.

So although we really have no idea what would happen over many, many generations, we can imagine that these might be aspects of human physiology that could start to be affected. We also have to consider the 'starter' genes for a space colony – the first inhabitants would likely be chosen to make excellent breeding stock. Genome sequencing pioneer Craig Venter has suggested that we could start screening potential astronauts for genes that would make good space travellers. He has also floated the idea of incorporating DNA from radiation-resistant microbes into the human genome. This could help us withstand damage from cosmic rays.



→ evolving? And if so, how will the human race look and behave in 1,000 years (see right), or 100,000 years?

Even if we look much the same, our genes may tell a different story. Right now, diseases like HIV and malaria are creating pressures for humans to adapt. The genetic traces of survival are like scars in our genome, but they also make us stronger. One example is a gene variant that is helping us battle against the onslaught of malaria. If a child gets a copy from both parents, it inherits a blood disorder called sickle cell anaemia, but a copy from just one parent offers protection from malaria, meaning this gene has spread rapidly in malaria-ravaged regions. In 2010, UK and Kenyan scientists mapped the spread of the sickle cell gene, confirming that areas of Africa where the gene is most common overlap with areas where malaria was rife.

One key feature of natural selection is that it has an effect before or around

reproductive age. So while technologies like transplants and medicines, more commonly used by older people, will have little impact on the genes we pass to future generations, diseases that kill at childbearing age or younger are powerful selectors. And in the arms

“You would expect that there would be [natural] selection for people who are immune to HIV”

Martin Blaser, a microbiologist at the New York University School of Medicine in New York

race with these deadly pathogens, our immune systems are accumulating weapons. HIV resistance is the best example of this, says Martin Blaser, a microbiologist at the New York University School of Medicine in New York. “This is natural selection in action,” he says. He explains that some people’s immune systems are less susceptible to the virus. They have a gene deletion called CCR5-delta 32, which stops HIV entering their cells – a deletion that should, by Blaser’s estimation, be spreading.

So will geneticists of the future be able to track the spread of HIV-resistance through the 21st Century, just as we spotted the spread of milk-digesting genes? “It depends if we get a cure for HIV,” says Blaser. “If there were no cure, then you would expect that over time there would be selection for people who are immune. That’s what Darwin would have predicted.”

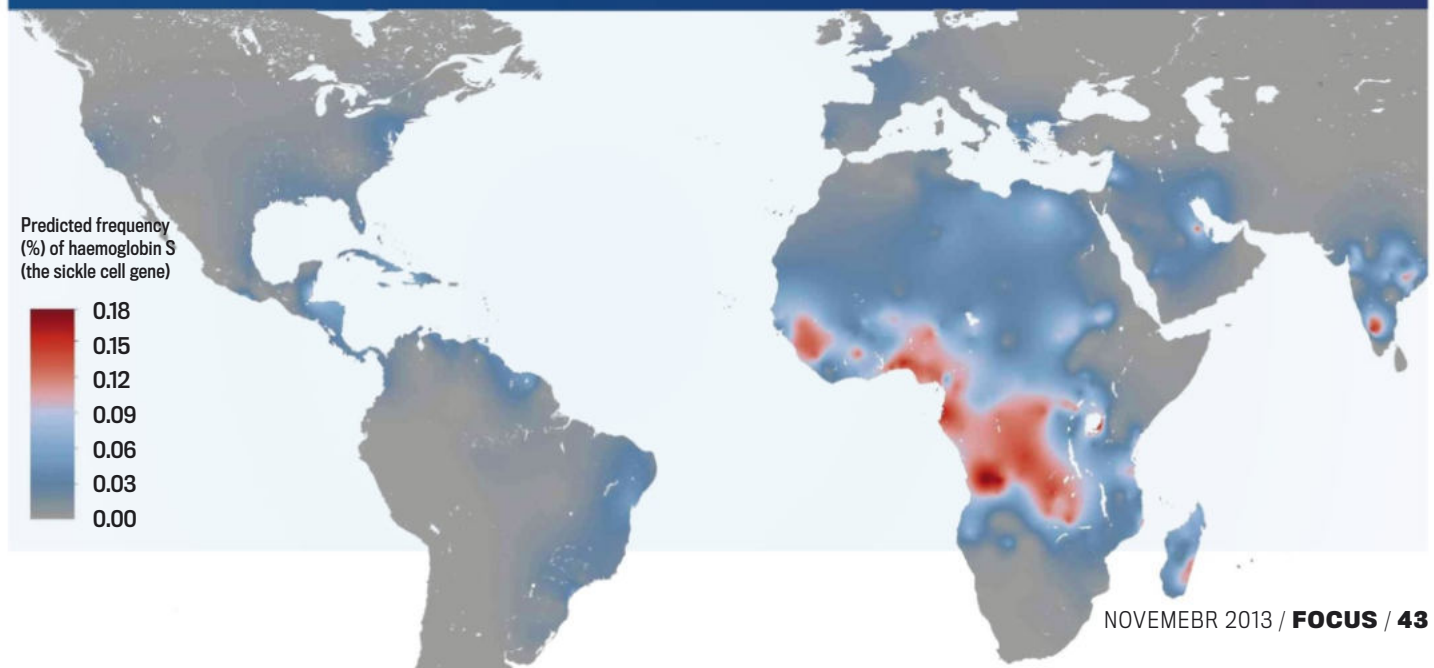




From right to left, US astronaut Thomas Marshburn, Russian cosmonaut Roman Romanenko and Canadian astronaut Chris Hadfield celebrate having spent half a year on the International Space station

EVOLUTION IN ACTION

The map below shows how the genetic variant that bestows a resistance to malaria is spreading across Africa and India, the two regions most affected by the disease

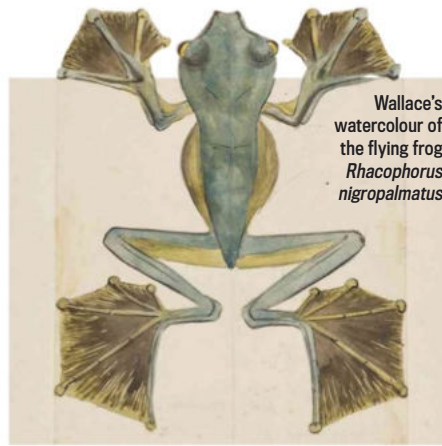


Despite the value of these adaptations, they do seem rather subtle. Why not something more radical? Why not webbed feet and gliding flight, like Wallace's flying frog? Well, besides the fact these trophy traits took millions of years to evolve, there are plenty of arguments against such dramatic changes. One is that our ability to continent-hop and persist in just about every available space means we now make babies wherever we choose, with whoever we choose – we're cross-breeding in a way that makes it difficult for new mutations, and new traits, to get established.

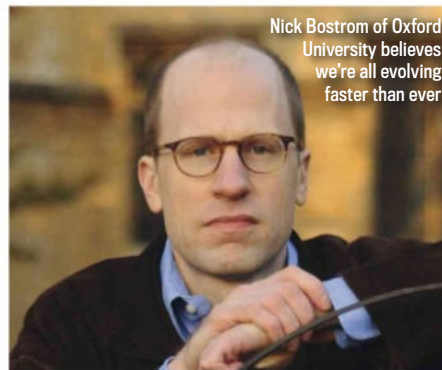
Isolation is a better way to direct evolution down a specific path, sometimes leading to new species altogether. So what if Britain formed its own splinter population? Maybe we could evolve tea-sucking trunks and extendable umbrella arms? A slightly less far-fetched isolation scenario is the colonisation of other planets (see 'Adapting To The Space Age' p46), although it would be a forward-thinking group of space pioneers indeed who set out to start a new species.

MAN-MADE EVOLUTION

There's a way to speed up evolution though – circumvent natural selection and isolation, and make your selections artificially. When fertility doctors carrying out *in vitro* fertilisation are deciding which embryo to implant, they choose the healthiest-looking one. So what if we could choose the one with brains like Einstein, a face like Marilyn Monroe, or legs like Usain Bolt? The trouble is that these traits are controlled by many different genes, so



Wallace's watercolour of the flying frog *Rhacophorus nigropalmatus*



Nick Bostrom of Oxford University believes we're all evolving faster than ever



Sexually selected traits, like the size of a peacock's tail, are constrained by predators

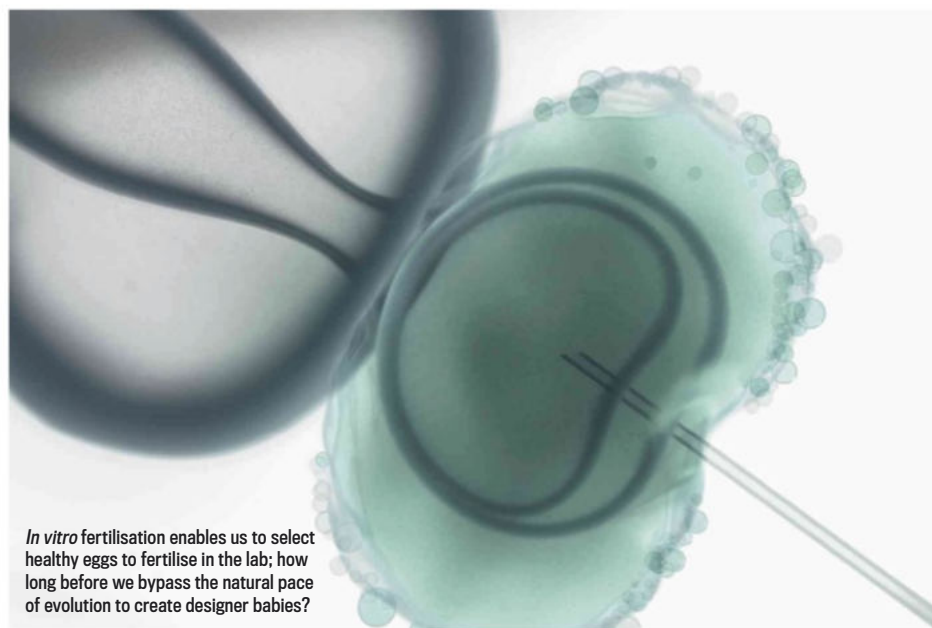
"What if we could choose the one with brains like Einstein, the face of Marilyn Monroe, or legs like Usain Bolt?"

we can't just test for brains, beauty or athletic ability. But Bostrom believes that in the future, parents will be able to gene-screen. "I think that as we're able to conduct genetic studies on much larger populations, we'll be able to detect at least part of the genetic basis for traits like intelligence that depend on the combined effects of large numbers of genes," says Bostrom. "Once we have that knowledge it can also be used to select which embryo to implant."

If the idea of picking out genetically superior children doesn't appeal, perhaps we could wait around a few thousand years for the leisurely process of evolution to catch up? By then, we should all be cleverer and cuter, right? This is where things get complicated. Beauty is considered a product of natural selection's dirty little sidekick, sexual selection, dictated by who mates with who. But natural selection and sexual selection often pull in opposite directions, as Steven Gaulin, an anthropologist at the University of California, Santa Barbara, explains. "Most sexually selected traits are bound by the counterbalancing effect of natural selection," he says. "Think about the peacock's tail. Females prefer long tails, but only a small fraction of the long-tailed males will survive the ambushes of foxes or whatever is hunting them. The net effect will determine how long a tail can get."

So we humans should ponder the costs of becoming super-attractive to the opposite sex – what is it that natural selection is doing to prevent us all from becoming swimwear models? Meanwhile, our impatient pursuit of physical perfection continues in ways that transcend evolution altogether. Although Bostrom says he considers human genetic engineering to be a long way off, gene doping is another matter. Whispers of concern began in the 1990s when scientists made 'Arnold Schwarzenegger' mice with giant muscles.

Attention soon turned to gene therapies. Rather than affecting the genes in embryos, gene therapies target DNA in adult cells, meaning they are ripe for abuse



In vitro fertilisation enables us to select healthy eggs to fertilise in the lab; how long before we bypass the natural pace of evolution to create designer babies?

SUPER-FAST EVOLUTION

The human body is able to quickly modify itself if the environment demands it

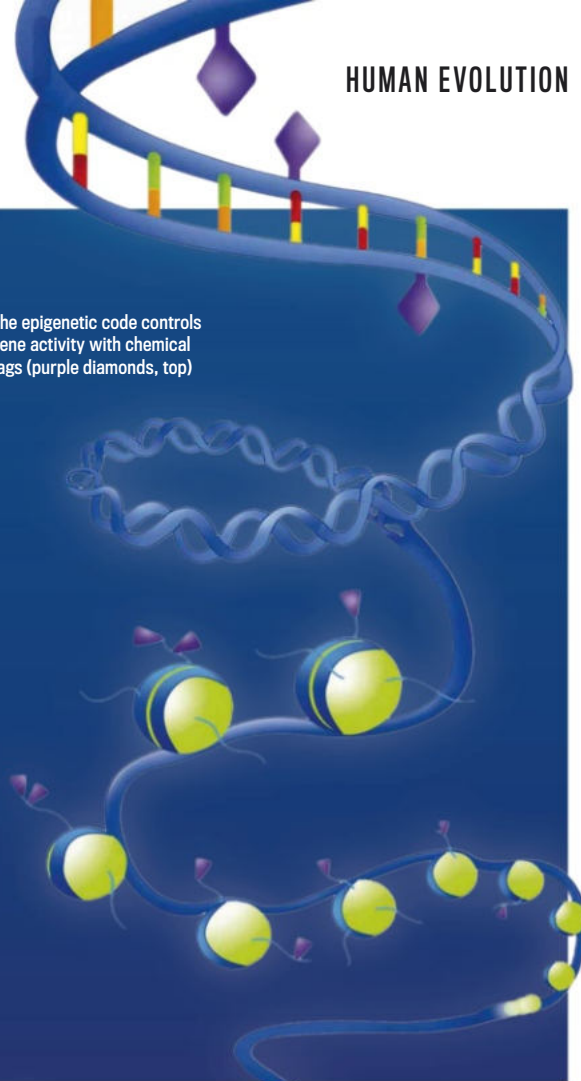
IT'S EASY TO forget that Darwin and Wallace never wrote about genes; they wrote about selection and adaptation. Our modern understanding means we attribute most examples of natural selection to genetic changes. But we are now learning that there is another layer of control – the epigenome – that could be driving human adaptations over much shorter time frames.

The epigenome refers to how DNA is packaged and modified, in ways that can profoundly affect our physical character. It can turn off some sections of the genome completely. For instance, there are many genes encoding the olfactory system – our sense of smell – that we do not need. So they are set to

'off' by the epigenome, through heavy chemical modification.

A 2013 study published in *Genome Research* suggests humans may use this mode of instant adaptation to produce rapid changes in skin pigmentation, as well as to protect themselves from diseases such as measles and Hepatitis B. "If an organism, an animal or a human, requires a quick change that confers an advantage to survive, it is more likely that an epigenetic modification takes place first," says lead researcher Manel Esteller from the University of Barcelona. "In our study, we also show there is cross-talk between genetic and epigenetic variants in humans to create a fine-tuning of humans to excel in different habitats."

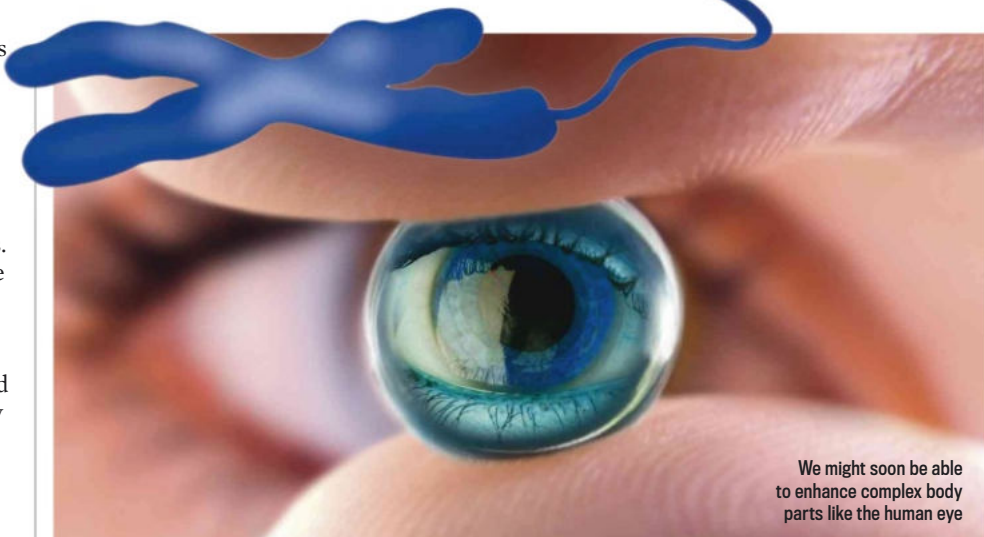
The epigenetic code controls gene activity with chemical tags (purple diamonds, top)



by drugs cheats. In 2007, a German athletics coach was accused of trying to buy an experimental gene therapy, Repoxigen, which ramps up production of red blood cells, therefore mimicking the effects of high-altitude training. Genes for muscle production and metabolism have been named as other potential targets for cheats.

In years to come, we could even replace feeble or damaged muscles with artificial ones. Smart materials called electroactive polymers have already been used as artificial muscles for focusing bio-inspired lenses, bringing to mind bionic eyes. They could also give movement to paralysed people – an idea tested by embedding the materials into the faces of gerbils. But could they drive artificial limbs or endow human biceps with superstrength? "The material performance today is not adequate," says Federico Carpi, a biomedical engineer at Queen Mary University of London. "But that does not mean that the technology will not be able to meet the goal one day." For now, at least, evolution has the upper hand.

Whatever the future might hold, Bostrom thinks there's good reason to speculate. "We base our decisions on expectations of what's plausible and what's crazy to believe about the future," he says. "So one reason it's important to



We might soon be able to enhance complex body parts like the human eye

think about the future is that if we have slightly better calibrated expectations we can make better decisions today." And when you can speculate, why not imagine a future where humans have uploaded their brains to computers, effectively making evolution – and biology – obsolete? Nick Bostrom does. ■

HAYLEY BIRCH is a science writer and author of *The Big Questions In Science*

Find out more



Listen to *Human Evolution*, an episode of *Frontiers* on BBC Radio 4 <http://bbc.in/Lre4ba>



Events, talks and exhibitions celebrating Alfred Russel Wallace hosted by the Natural History Museum <http://tinyurl.com/d3v6yc5>



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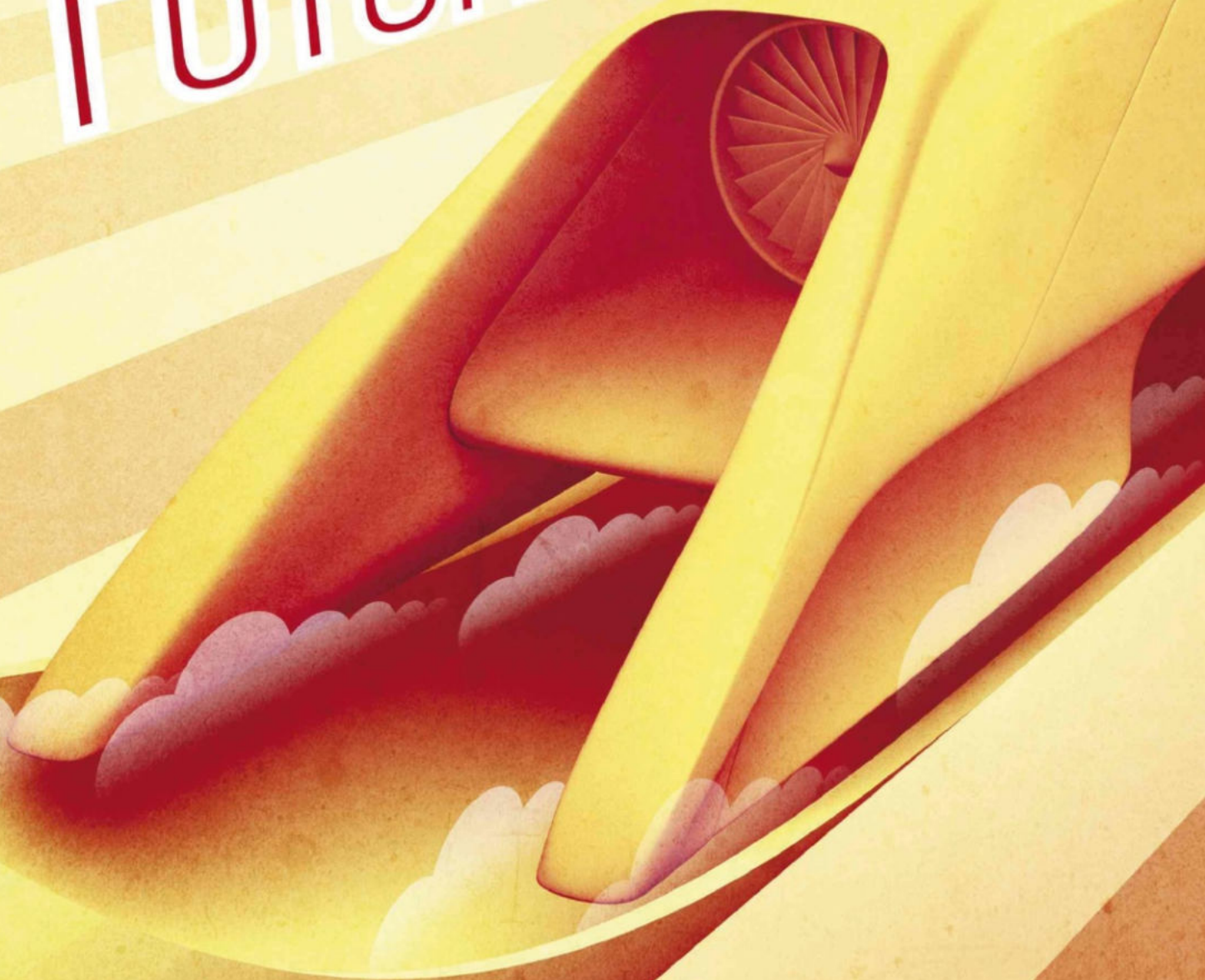
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ALL ABOARD THE FUTURE EXPRESS





Meet the machine that could carry commuters faster than the speed of sound. Stuart Nathan explores Elon Musk's Hyperloop, and the trains that will change transport forever

MILLIONS OF PEOPLE commute to work by Tube, whether they call it the Underground, the Subway or the Metro. But if US technology entrepreneur Elon Musk has his way, tube travel will take on a whole new meaning.

Frustrated with the shortcomings and cost of the planned Los Angeles to San Francisco high-speed rail line, Musk has come up with a combination of two high-tech science-fiction staples of train travel: the vacuum train and the magnetic levitation (maglev) train. Called the Hyperloop, the system would run pods through an elevated tube, shooting passengers along the coast of California like bullets in a gun barrel.

These vactrains work by propelling carriages along an evacuated tube.



INSIDE THE HYPERLOOP

How do you travel nearly 600km in under 40 minutes? Elon Musk's 'fifth mode of transport' could be the answer

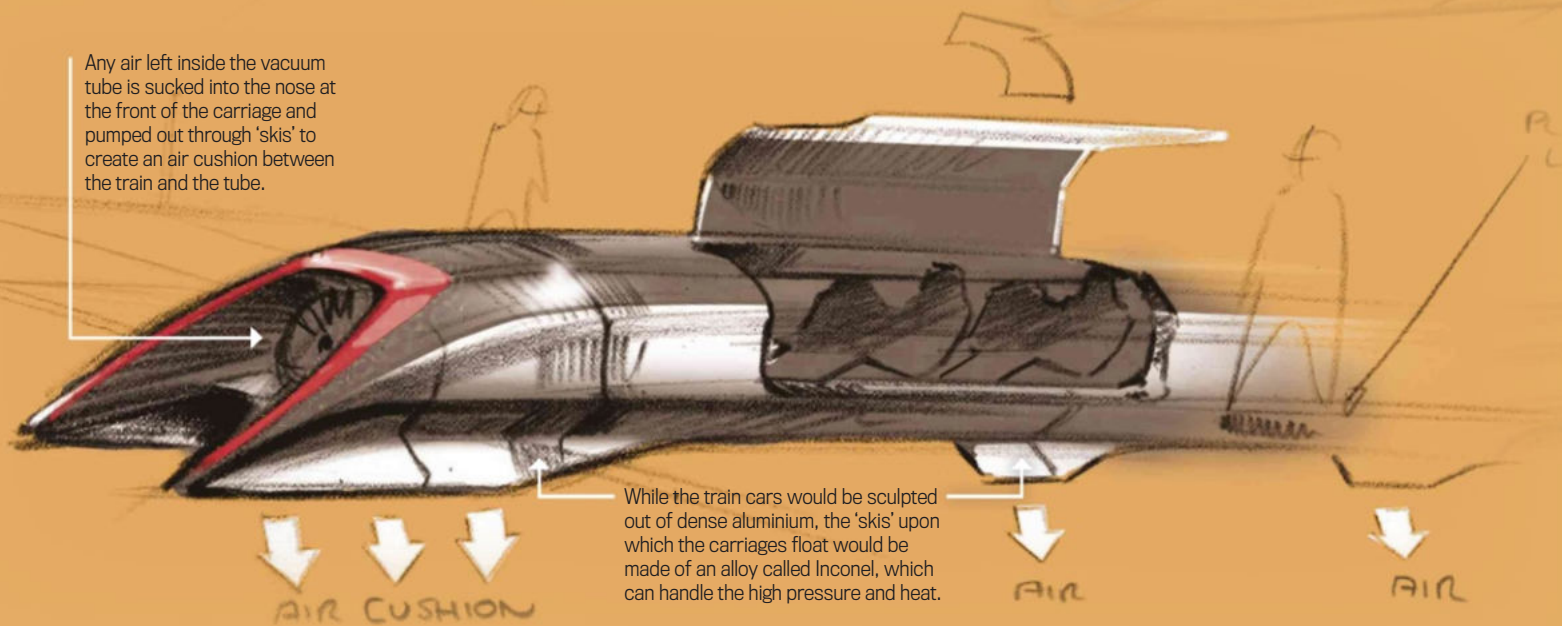


The proposed route of the Hyperloop tube would carry it along the Interstate 5 Highway that connects San Francisco and Los Angeles. Raised on 6m-high pylons, the tube would limit environmental damage and reduce costs.

FORGET BOATS, PLANES, trains and cars, Elon Musk – the pioneer behind Tesla and SpaceX – wants to create a fifth mode of transport: a vacuum tube. His vision would get commuters from Los Angeles to San Francisco, and vice versa,

in 35 minutes, at a fraction of the cost of a high-speed railway. While Musk won't be building the Hyperloop himself he's offered up these blueprints – along with full specifications – to anyone bold enough to make it a reality.

Any air left inside the vacuum tube is sucked into the nose at the front of the carriage and pumped out through 'skis' to create an air cushion between the train and the tube.



While the train cars would be sculpted out of dense aluminium, the 'skis' upon which the carriages float would be made of an alloy called Inconel, which can handle the high pressure and heat.

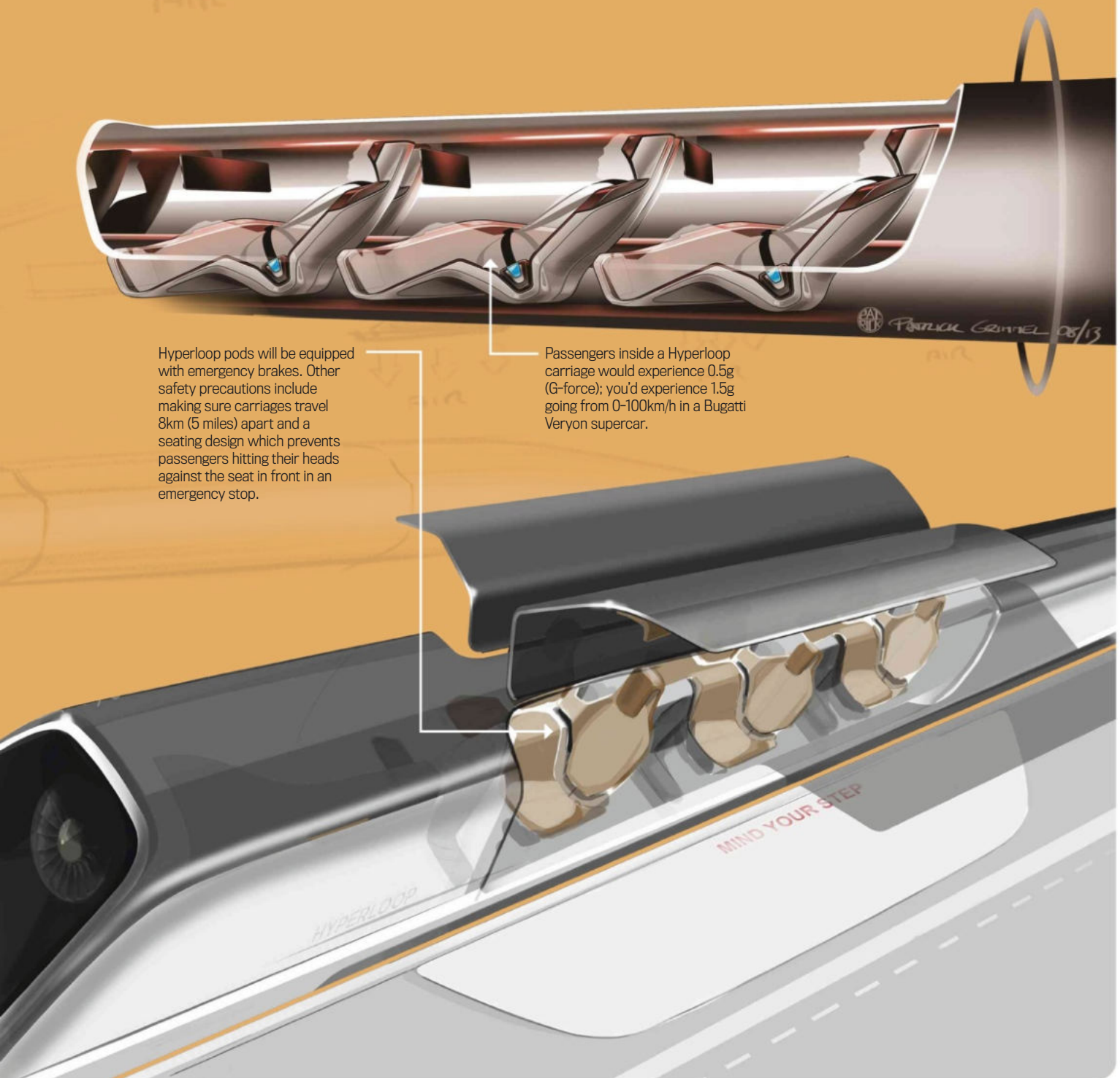
➔ The lack of air resistance means that they can reach terrific speed, theoretically exceeding the speed of sound – no air means no sound barrier. But vactrains have always been a conceptual technology, thought too difficult to actually turn into reality. Musk has adapted the ideas to remove some of the potential drawbacks while still keeping many of the advantages.

It's difficult to create a perfect vacuum, so Hyperloop instead runs at a reduced

pressure, about a thousandth of an atmosphere. The transport pods are equipped with compressors in their noses to suck the air out of the way and divert it to skis underneath, creating a hovercraft-like air cushion to lift the pod clear of the floor of the tube.

Power for forward motion comes from linear electric motors. Because of the lack of friction or air resistance in the tube, these wouldn't have to be continuous – one linear strip every 100km or so

would be sufficient to accelerate the pods up to 1,220km/h (696mph) – only a little short of the current world land-speed record. The pods would slide on skis made from Inconel, a nickel-chromium alloy with extraordinary temperature resistance. Even so, each pod would have to carry 800kg of water for cooling. Such speeds could see a Hyperloop pod complete the 563km (350-mile) journey between LA and San Francisco in about 35 minutes – about half the time it currently takes to fly.



Hyperloop pods will be equipped with emergency brakes. Other safety precautions include making sure carriages travel 8km (5 miles) apart and a seating design which prevents passengers hitting their heads against the seat in front in an emergency stop.

Passengers inside a Hyperloop carriage would experience 0.5g (G-force); you'd experience 1.5g going from 0-100km/h in a Bugatti Veyron supercar.

All of this will require energy, of course, but sunny California will provide all the electricity the system needs – and more, according to Musk – through high-efficiency photovoltaic panels built into the top of the tube. Musk claims that the panels would generate 57MW of power, which is three times as much as he claims the system would consume.

The tube itself – or rather pair of tubes, as they could only operate in one direction – would ride above the landscape on

6m-tall pylons placed every 30m or so along the route. In all, there would be at least 25,000 of them. Because of the somewhat unstable nature of California, each pylon would be equipped with an earthquake damper, and the route would follow the existing I-5 interstate road, which would keep the cost down.

Musk claims that the whole system would cost about \$7 billion (£4.4bn), set against the projected \$68 billion (£43bn) for the California High Speed Rail project.

Elon Musk certainly has form and finances – he co-founded PayPal. But despite launching Tesla Cars, commercial space enterprise SpaceX, and the photovoltaics company Solar City, he wants somebody else to develop it, although he might work on a demonstration model himself. If it works, it could change the face of medium-range travel completely. If it doesn't, it'll be the latest in a long line of vactrain concepts consigned to the realms of science fiction.



OFF THE RAILS

The Hyperloop isn't the only radical locomotive design we can expect to see in future

CLIP-AIR

THESE DESIGNERS TOOK the term 'blue-sky thinking' a little too literally. The École Polytechnique Fédérale de Lausanne (EPFL) has designed a form of transport which, it says, combines the flexibility of train travel with the reach of planes. Clip-Air is a train carriage, which is designed to attach to a pair of wings with engines.

EPFL has a prior track record for delivering on outlandish ideas. It's a major technology centre in Switzerland, whose facilities include a nuclear reactor, Tokamak nuclear fusion reactor, and research projects including the autonomous solar-powered aircraft Solar Impluse.

The Clip-Air train carriage is an aircraft fuselage, designed to travel by rail to an airport. Once

there, it attaches to a 'flying-wing' aircraft, similar to the experimental Boeing X-48B. The aircraft can carry three 'carriages' side by side, carrying passengers, cargo or a combination. According to research leader Claudio Leonardi, it would be faster to board than a conventional aircraft and simpler to maintain. His team hopes to undertake aerodynamics research with a 6m-long flying model soon.

Taking a journey by CLIP-AIR means you'd board your flight at the railway platform



ECO4

TRAINS HAVE ALWAYS been seen as an environmentally friendly mode of transport, but this design takes it a step further. Train manufacturer Bombardier's ECO4 is a family of technologies. It uses an ultra-efficient magnetic engine system that draws energy from solar cells mounted to the roof. These rotate to track the Sun and if it's built will make it the world's first solar-powered train. The carriages will be made of carbon fibre composites, making it strong but lightweight. Since it'll be a commuter train system, the ECO4 will use a hybrid engine to keep it running through our dark winter months. As well as being energy efficient, the ECO4 train is designed to insulate passengers from engine noise.

The ECO4 pulls together a range of technologies to make it ultra-efficient





The Chūō Shinkansen wows the press with its lightning pace and 15m-long aerodynamic nose

CHŪŌ SHINKANSEN

THE LAND OF the Bullet Train is now aiming to go one step further with a fully-fledged maglev high-speed train. The Chūō Shinkansen is planned to connect the cities of Nagoya,

Tokyo and Osaka, and is based on technology currently being developed on a 42.8km (26.5-mile) test track in Yamanashi prefecture.

Existing maglev trains use magnetic rails to lift trains off the ground, where they're held and pushed towards their destinations.

Since maglev trains simply levitate, they don't lose any speed to ground friction, allowing the carriages to accelerate to speeds of up to 321km/h (200mph). The Chūō Shinkansen trains use a similar premise but with much more efficient 'superconducting' rails, as well as a radically streamlined design. They're lighter than the predecessors too, using lightweight aircraft-grade aluminium alloys and composites, with minimal glass to shed further kilos. Test trains running on this line have achieved speeds of 500km/h (310mph), and the service is due to open to the public later this year. The entire line will be an extension of this test track, and is scheduled to cost a total of ¥9 trillion (£44bn). The line is due to be completed in 2045, although Shinkansen services between Tokyo and Nagoya will begin in 2027.

LABIS

THE LASHLEY ADVANCED Bi-Rail System (LABIS) is designed to be the trans-American high-speed train that doesn't stop. Travelling on elevated tracks, the trains are wide-bodied (six

passengers abreast plus tables and aisles), which makes them stable, with powered carriages. This, the designers say, avoids the need to over-engineer carriages to cope with the stresses of being pulled

along by one end.

The train itself keeps moving at a speed of some 320km/h (200mph) and doesn't stop. Passengers embark and disembark via shuttle vehicles, which stop at a station located on a parallel track. These pick up passengers, rejoin the mainline, catch up with the main train and dock onto the back. This allows passengers to board the main train and let disembarking passengers get on. When everyone who wants to leave is on board, it undocks, goes onto another parallel line and stops at the next station. The entire transcontinental journey would take about 14 hours. ■



You won't be waiting for the LABIS train to arrive - it never stops

STUART NATHAN is features editor of *The Engineer* magazine

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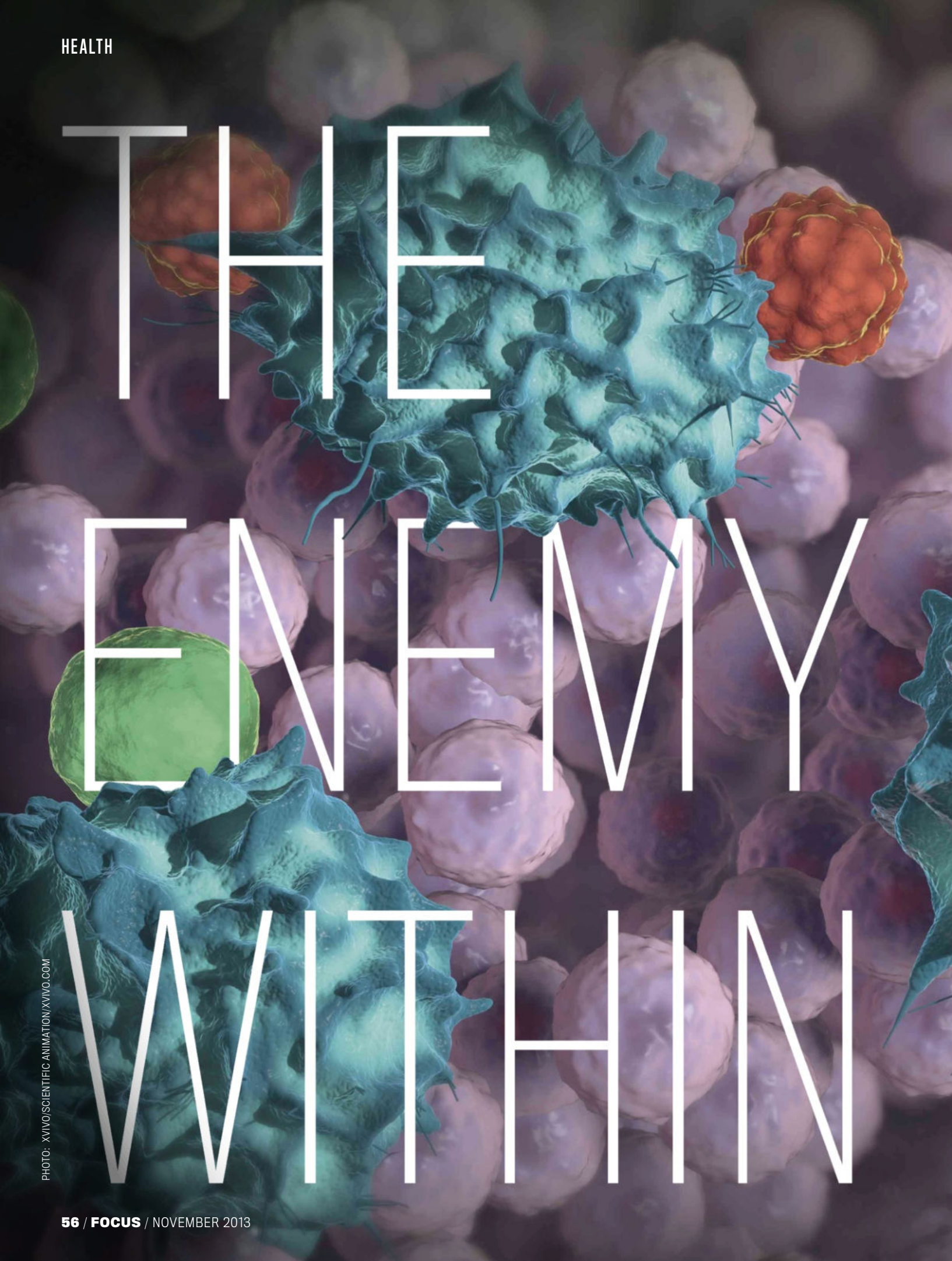



PHOTO: XVIVO/SCIENTIFIC ANIMATION/XVIVO.COM

An artist's impression of Peyer's Patch, an area in the gut filled with immune cells. The image shows a large, textured, greenish-blue structure in the foreground, surrounded by numerous smaller, rounded cells in shades of pink, orange, and green. The background is dark and out of focus.

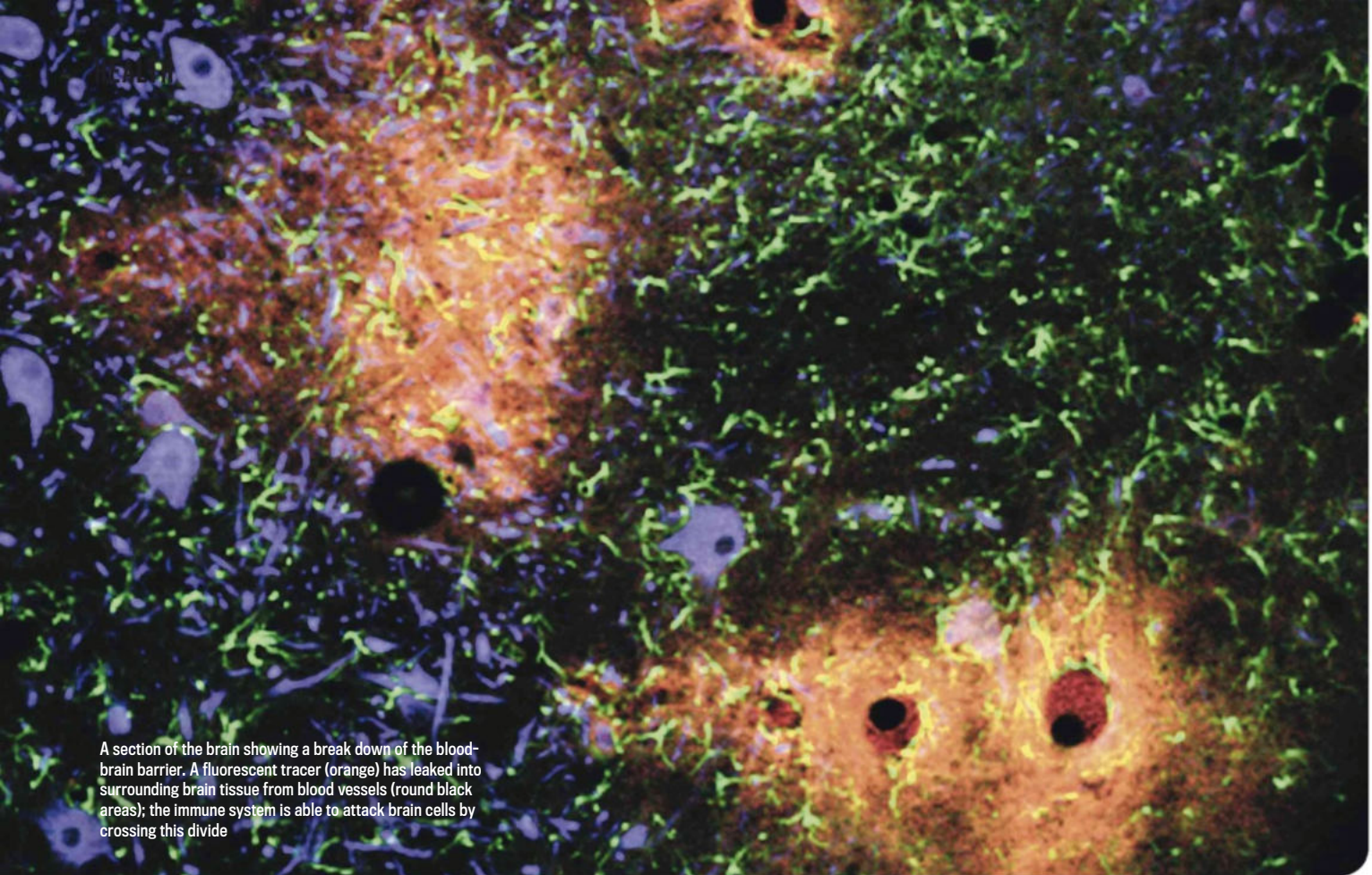
From dementia to depression, the science of neuroimmunology is revealing how our own body can attack the brain. **Susannah Cahalan** explores the condition that has affected her and thousands of others

THE SPASMS BEGAN in his right arm. Two years ago, John, a DIY store owner from London, noticed that his dominant hand would awkwardly lock-up and bend at unnatural angles for several seconds at a time. He was conscious but couldn't control his movements. The spasms repeated, over and over, several times a day, until it moved to include his left hand and later climbed up both arms and legs and even his face in a frighteningly progressive dance of limbs.

John, whose name has been changed to protect his patient privacy, began to lose memories. When his wife mentioned their recent trip to Egypt, he blanked on what was a memorable journey down the Nile. The spasms ratcheted up in intensity, plaguing him upwards of 100 times a



An artist's impression of Peyer's Patch, an area in the gut filled with immune cells (blue, orange and green cells)



A section of the brain showing a break down of the blood-brain barrier. A fluorescent tracer (orange) has leaked into surrounding brain tissue from blood vessels (round black areas); the immune system is able to attack brain cells by crossing this divide

→ day. His baffled local doctor referred him to a neurologist, who conducted a battery of tests – MRI, EEG, lumbar puncture – all of which came back clean. What could possibly explain these bizarre episodes?

“It’s psychogenic,” the neurologist told him, using a word applied when physical symptoms are caused by emotional or psychological causes. In other words, he really was saying, “It’s all in your head.” There was no treatment, instead he told him, “It will get better on its own.”

Luckily, Dr Sarosh Irani, an Oxford University neurologist, had seen cases like this before. When he met John he was almost certain he was dealing with a condition called ‘faciobrachial dystonic seizures’ – a newly discovered form of autoimmune disease that he and fellow researchers from London and Australia had been studying. His condition wasn’t psychological in origin; instead, the seizures were the result of the body’s immune system targeting and attacking the brain.

While waiting for blood tests to confirm the diagnosis, John received several doses of steroids, a medication used to treat autoimmune diseases because it reduces inflammation in the body and suppresses the immune system. Within 10 days, the seizures had stopped. Otherwise written off as psychogenic, now John could return to his normal life. And

though striking, John’s is not a unique story. I was also a direct beneficiary of the field’s medical progress. Just five years ago, I was diagnosed with a newly discovered form of autoimmune encephalitis that nearly went misdiagnosed as a mental illness.

In the last decade there’s been a growing fascination with the interaction between the brain and the immune system. For so long, the brain has been the focus of intensive study, while the immune system, the under-appreciated, unsung hero of the body, has been largely overlooked. No longer. Now cutting edge research into the body’s immune system and its relationship with the nervous system reveals that some diseases once believed to be neurodegenerative or untreatable might actually be curable. There may even be a host of undiagnosed conditions resulting from the body’s own defences turning on itself.

“Now what we’re seeing in a minority of patients with very standard neurological symptoms, like seizures, encephalitis [swelling of the brain], or dementia, is that they have diseases that are treatable with drugs that would never have been considered five or 10 years ago,” Dr Irani told *Focus* magazine. “Physicians,

“We started to rapidly identify new antibodies, new antigens, and new diseases”

Dr Josep Dalmau, senior investigator, Hospital Clinic, University of Barcelona

who were once missing diseases, can now treat their patients.” Some researchers suspect that defects in the autoimmune system could be playing a role in conditions as wide-reaching as heart disease, epilepsy, dementia and even psychiatric illnesses like depression and schizophrenia.

In a healthy person’s body, immune cells produce antibodies, forces for ‘good’ in the fight against pathogens like viruses, bacteria or parasites. But

when things go wrong, antibodies begin to target the body’s healthy tissue. In the brain, they attack neurotransmitter receptors and channels – the

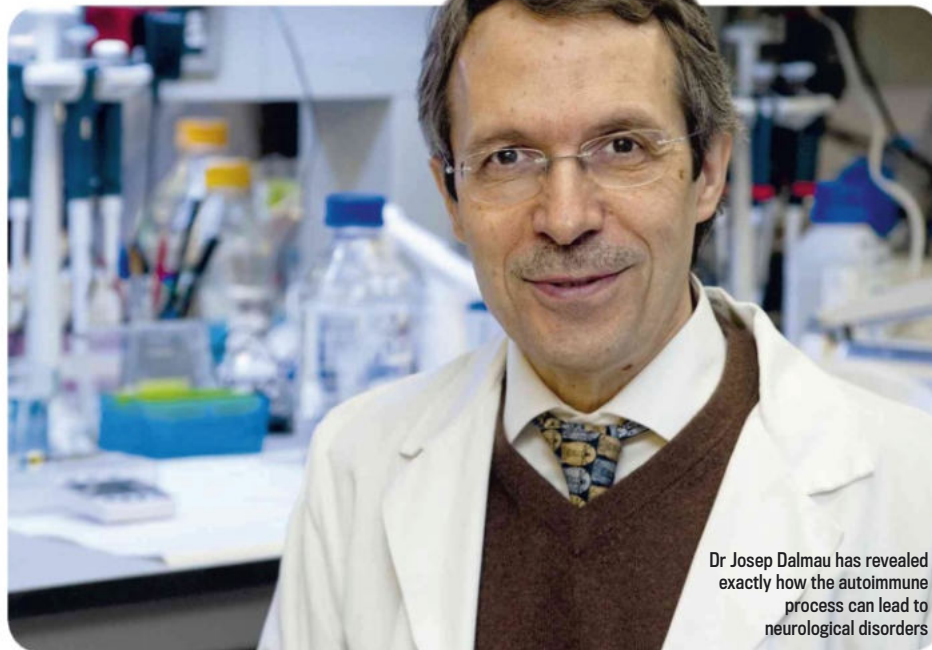


medium for communication between brain cells – begetting devastating results. It's thought that these antibody-mediated diseases affect around 4,000 patients a year in the UK. This might not sound like a lot, but the potential number of patients left undiagnosed has excited doctors. New research initiatives have launched around the world with the goal of pinning down exactly how many people could be affected. "Textbooks are a waste of time in this field," said Professor Angela Vincent, who directs a lab at Oxford University that studies diseases caused by autoantibodies. "There is too much progress for textbooks to keep up."

CLINICAL PROGRESS

It's only become general knowledge since the mid-1990s that immune cells could even cross the blood brain barrier – a layer formed by a patchwork quilt of blood vessels to protect the brain from pathogens in the rest of the body. What followed was a veritable domino-effect of scientific progress. Researchers found that antibodies crossed the blood brain barrier when certain cancers were present in the body, a disease set called paraneoplastic syndrome.

In 2005, Dr Josep Dalmau of the University of Pennsylvania released a



Dr Josep Dalmau has revealed exactly how the autoimmune process can lead to neurological disorders

ground-breaking study describing a small group of female patients who had a treatable form of autoimmune encephalitis, exhibiting psychosis, mood disturbance, aggression, delusional thinking, and seizures. He later found antibodies had been targeting and binding to a specific chemical receptor in the brain important

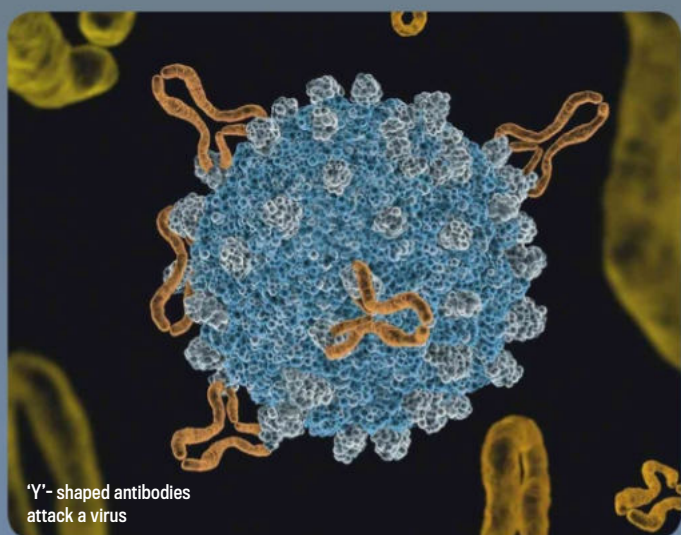
to learning, memory, and behaviour. With proper treatment, these 'NMDA-receptors' were freed, making it a remarkably treatable disorder.

"People started paying a lot of attention in 2005 as we started to rapidly identify new antibodies, new antigens, and new diseases," says Dr Dalmau.



HOW THE IMMUNE SYSTEM DEFENDS... AND ATTACKS

The body is able to defend itself from millions of threats with a remarkable system of cells that churn out an army of antibodies



'Y'-shaped antibodies attack a virus

THE IMMUNE SYSTEM is broken down into two types of white blood cell: the T-cells and the B-cells. Developed in bone marrow, T-cells and B-cells serve a variety of functions in the body, among them helping to combat infections caused by viruses, bacteria and other 'bad things' called pathogens. Some B-cells morph into plasma cells, which create antibodies, 'Y'-shaped proteins that aid in the immune system's fight by identifying, neutralising, and triggering a wide-scale immune response. The tips of the arms of each antibody (the

binding sites) are so specific to each antigen (or binding site on a pathogen) that scientists estimate that well over 100 million different antibodies can be created in the human body.

In the case of autoimmunity, the 'antigens' that the antibodies target are located in the body's healthy tissue itself. For example, in the case of autoimmune encephalitis where the brain swells after being attacked by the immune system, antibodies begin to target the brain's neurotransmitters or protein channels, causing a kind of self-inflicted disease.

HARNESSING THE POWER OF THE IMMUNE SYSTEM

The attacking capabilities of the immune system can be put to use fighting cancer

AS OUR UNDERSTANDING OF the diseases of the immune system grows, researchers are beginning to harness its power to design targeted drug therapies for more widespread diseases, like cancer.

One such drug, still early in testing phase, reprograms the immune system to combat cancer cells. The drug disables what's known as 'programmed cell death' in immune cells. In other words, it turns off the proteins that modulates the immune system's response. The belief is that by setting cell death to 'off', the immune cells won't restrain themselves and will mount a more robust response

to cancer, which might one day offer an alternative to chemotherapy.

Another experimental drug relies on a similar principle, but instead employs a disabled form of the HIV virus to wipe out blood cancers. This treatment relies on the altering of a patient's T-cells, a type of white blood cell that battles infection, among other roles. The disabled HIV viruses infect T-cells with 'messages' to attack and destroy B-cells, another type of white blood cell and the source of the disease in cancers like leukemia.

Once perfected, these fine-tuned approaches to treatment will cut down on side-effects that can sometimes be devastating. At the moment, drugs that involve or manipulate the immune system are like "sledgehammers", says Dr Sean Pitcock at the Mayo Clinic in the US. "This is a great opportunity to develop drugs to benefit patients. [In the future] we can hopefully develop finer, more bullet-directed drugs."



"When physicians realised that there were some groups of diseases in this expanding category that were easy to identify and actually treat, it garnered a lot of attention."

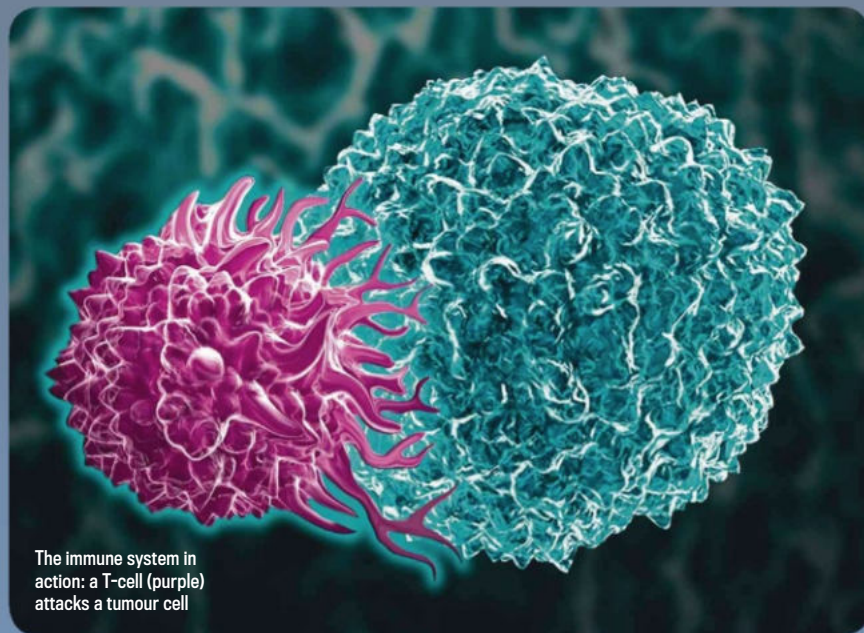
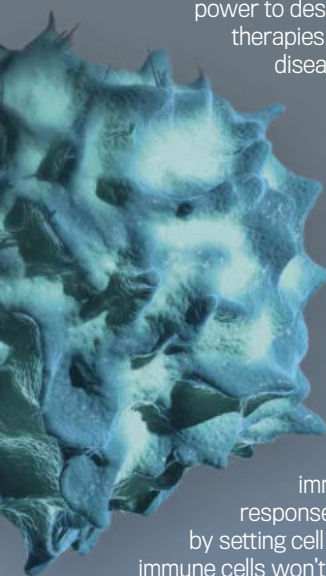
Now researchers have discovered at least 13 different types of autoimmune encephalitis that are caused by antibodies. This year, Dr Dalmau published a paper in the medical journal *The Lancet* describing nearly 600 patients with NMDA-forms of autoimmune encephalitis, many of whom saw psychiatrists during their first week of symptom presentation. Among them, only around four per cent displayed psychiatric symptoms (meaning no neurological presentation, like seizures). The implications of these findings, despite the small sample size, are still reverberating through the psychiatric and neurologic community.

"It was very exciting to realise that there is a disease in which patients would never have gone to neurology, but would have been sent to a psychiatric ward or facility with a wrong diagnosis, at least during the first months of the illness," said Dr Dalmau, who now runs the neuroimmunology programme at the University of Barcelona, Spain. Others have tried to expand on Dr Dalmau's research – by attempting to link underlying autoimmune mechanisms with classical psychiatric diseases like depression, obsessive compulsive disorder, post traumatic stress disorder, and bipolar disorder – with less concrete results.

A study conducted by Loyola University of Maryland in the US found that patients diagnosed with depression have higher rates of inflammatory immune cell molecules called interleukin-6 than the general population. These molecules are associated with cardiovascular disease. Another study from Denmark, published in *JAMA Psychiatry*, showed that those with autoimmune diseases had a 45 per cent higher likelihood of developing a mood disorder. However, the study's authors admitted the exact nature of the correlation is hard to untangle.

PHYSICAL SYMPTOMS

The link between psychiatry and autoimmunity is tenuous at best, but there are still promising findings in other fields of medicine. Take the aforementioned John. Dr Irani found that he had antibodies directed against one of the brain's chemical receptors present in his spinal fluid, confirming that his immune system was attacking his brain. John has now been seizure-free for 18 months and is being weaned off his steroid medication.



The immune system in action: a T-cell (purple) attacks a tumour cell

“Any receptor in the brain could be a potential target for the immune system”

Dr Sean Pittock, co-director of the clinical neuroimmunology lab at Mayo Clinic

Dr Irani's Oxford lab is now exploring if other types of epilepsy are caused by a rogue immune system. For instance, more than 20 per cent of epileptic patients have what's known as 'intractable epilepsy', meaning that it can't be treated with normal anti-epileptic drugs. Irani believes these cases might be the result of a glitch in the immune system, and could therefore be treated with immune system-based therapies.

Meanwhile, Dr Dalmau is continuing his studies, focusing on the links between viral encephalitis (largely untreatable) and autoimmune encephalitis. He's also working on a paper looking at a subset of narcoleptic (sleep disorder) patients that could perhaps be caused by antibodies targeting areas in the hypothalamus, an area of the brain that controls fatigue, sleep, and circadian rhythms.

The Mayo Clinic, based in Minnesota, is exploring what is now called 'autoimmune dementia'. In one study published in 2011, 72 patients who all exhibited acute cognitive decline, received immune therapy, mostly in the form of steroids. Of those patients, 46 improved across the

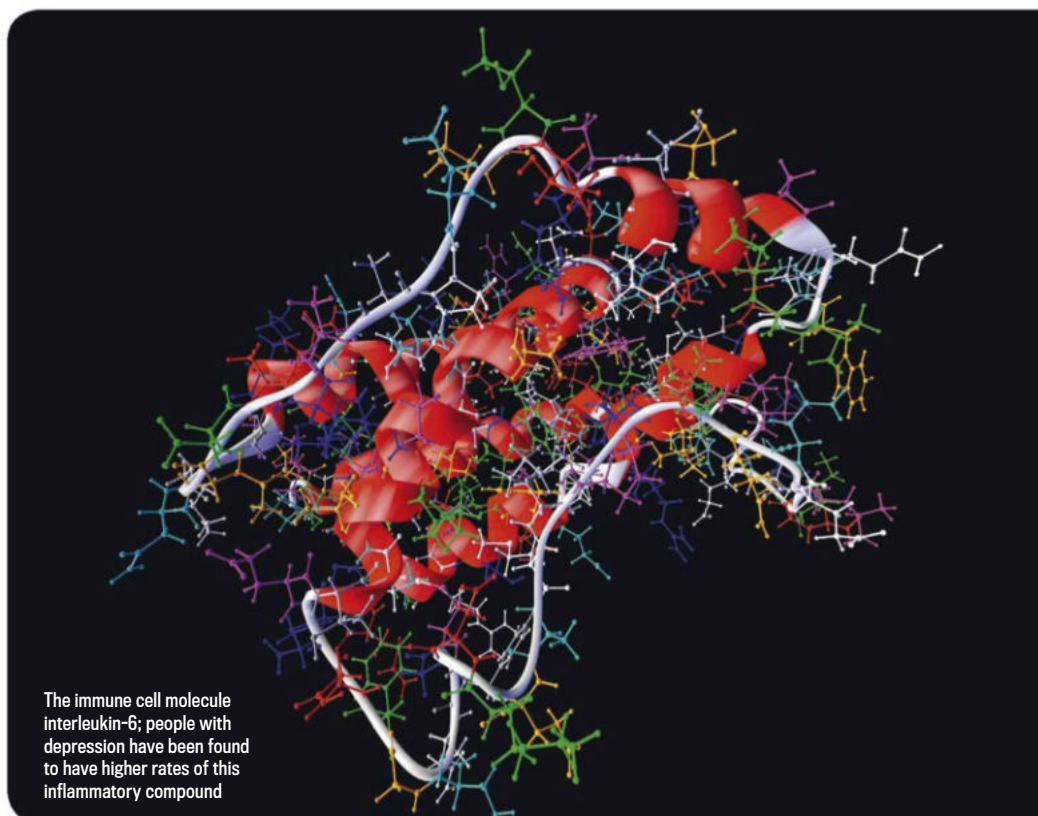
board, most notably in 'learning and memory' in the first week of treatment. And of those, 35 per cent had previously been diagnosed with a neurodegenerative dementia or prion disorder, both hopeless to treat. The study concludes, quite dramatically, that this 'suggests that autoimmune dementia may be under-recognised and the potential benefit of immunotherapy missed in many patients'.

"This is the concept that any channel or receptor in the brain that is involved with

neurological function – thinking, memory, behavior – could be a potential target for the immune system," said Dr Sean Pittock, an author on the autoimmune dementia paper and co-director of the clinical neuroimmunology lab and autoimmune neurology clinic at Mayo Clinic. "It's a new field and you're really only dealing with the tip of iceberg."

That's the key. The field has come so far in so few years, which begs the question: how much is there still left to discover? And how many patients are going undiagnosed? Just a few years ago John, the patient who opens this piece, would undoubtedly have been among the undiagnosed. To combat this, doctors are starting to treat patients without positive test results, going under the assumption that there is much more still unknown. "Now people who have excluded other diagnoses are saying, 'This 'smells' like an autoimmune disease,'" says Professor Vincent. "Many doctors are now starting to treat patients before – or if – they get positive results." ■

The clinic where Dr Sean Pittock (right) and colleagues study how the immune system could cause dementia



SUSANNAH CAHALAN is the author of *Brain on Fire: My Month Of Madness* (Penguin, £9.99), which describes her own battle with autoimmune encephalitis

DESMOND MORRIS

Is the human mind hardwired to create art? **Desmond Morris**, author of *The Naked Ape*, tells us why hunter gatherers liked to paint and the battling hemispheres of his brain

Words: Katherine Nightingale

Your new book, *The Artistic Ape*, is subtitled *Three Million Years Of Art*. Has art really been around for that long?

Most people think of the cave paintings in France from 15 to 20,000 years ago as the beginning of art. But the oldest art object is the three million-year-old Makapansgat Pebble, a stone with a face worn or carved into it, which was collected by an ape man or woman and taken to his or her cave in what is now South Africa. It was the first 'collectable'. There's no proof that they fashioned it but they certainly saw the face on it and took it home. It shows that even these pre-humans were responding to an image. I'm very lucky that when I was filming in Africa years ago I was allowed to hold it. That was the most thrilling moment in all my studies of art history.

How did art arise in humans?

We tend to think of art as a picture or a sculpture, but that's a very narrow view. Art began as a way of making a celebration. Humans have high levels of curiosity and our nervous system likes to be busy, so instead of going to sleep after hunting like a lion would, our hunter-gatherer ancestors would have had a great feast and celebration. We did this with song and storytelling and dancing – all the arts began at the primeval feast. Visual art began as self-decoration and display as part of these feasts.

In the book I'm trying to put art into its evolutionary setting, to show

"I'm trying to put art into its evolutionary setting, to show that it isn't some airy-fairy thing"

that it isn't some airy-fairy thing that we do in art school. Art is basic to the human species and is a human obsession. Every culture has some form of art – I've been to something like 107 countries and never found a place that was artless.

Is there anything that resembles art anywhere else in the animal kingdom?

We find beauty in things like male peacocks displaying their feathers, but that's not art because it's not manufactured. The first book I wrote, *The Biology Of Art* in 1962, was about picture-making by a chimpanzee. I was trying to study the origins of aesthetics and see to what extent a chimp could make pictures. To my surprise he was able to visually control his pictures, but they were always abstract rather than images of anything. There's nothing in tales of other animals 'painting' – they're either randomly splashing paint about or being led by their owners.

In *The Naked Ape* you studied human behaviour in the way a zoologist would study animals. Why are you focusing on something uniquely human now?

After *The Naked Ape*, people said "Doesn't he understand that humans beings are creative?" Of course I did, but I deliberately omitted things that are unique to humans: language, scientific enquiry and artistic expression. Now I've faced the challenge of looking scientifically at artistic creativity. It's difficult, of course, because the history of human art could fill hundreds of encyclopaedias. It's the most difficult book I've ever written, but now I feel relieved

that I've managed to get the ideas into print because it's something that's been in my mind for half a century.

***The Artistic Ape* brings together your passion for art and science. Have they complemented each other throughout your career?**

I've always said I use both hemispheres of my brain. I have my library next to my studio and these represent the two hemispheres of my brain. Most people have one hemisphere that's dominant. A mathematician is dominated by their analytical hemisphere and a poet is dominated by their imaginative hemisphere. My life has been strange in that right from an early age I've been fascinated by the analysis of animal behaviour on the one hand, and by art on the other. My painting and drawing is purely imaginative, and in my scientific work I've been analytical about human behaviour to a point that's upset people.

You did your PhD on the behaviour of sticklebacks. How did you get from studying fish to humans?

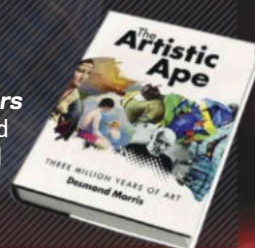
When I was very young I found my great-grandfather's microscope in the attic and discovered this strange world of biological shapes which influenced my painting. I did my doctorate on fish behaviour, and then my postdoctoral research on bird behaviour. Later I went to London Zoo to study mammals, ending up with chimpanzees, so it was as if I was climbing up the evolutionary tree – the next obvious step was humans. The reason *The Naked Ape* sold so many copies was that no one had ever studied humans as if they were just another animal. Even the chapter headings in my doctoral thesis are the same as those in *The Naked Ape*! ■

KATHERINE NIGHTINGALE
is a science writer with a degree in molecular biology



Find out more

The Artistic Ape: Three Million Years Of Art by Desmond Morris is published by Red Lemon Press (£30)





FORECAST FROM THE PAST

Could rising CO₂ levels see Earth returned to the kind of climate not seen since the prehistoric era?
Katharine Sanderson heads back in time

SUNDAY 13 MAY 2013 was just an ordinary working day for the air-sampling instruments of the Mauna Loa observatory, sitting on the slopes of a volcano in Hawaii. Those instruments have been keeping an eye on the air for decades, and nothing was different on that Sunday. But it was a significant day for humankind. For the first time, the instruments recorded carbon dioxide levels in the atmosphere of 400 parts per million.

Humans are responsible. We got to this point after a few short centuries of burning fossil fuels, and in doing so could be plunging our climate back into prehistory, returning the Earth to conditions it was last familiar with millions of years ago. The figure of 400ppm isn't particularly

significant in itself, but the number is symbolic, highlighting just how far levels of the greenhouse gas have risen since humans got busy with fossil fuels.

Carbon dioxide levels in the pre-industrial era (that is, up to the late 18th Century) stayed steady at around 280ppm. Up until then, for the past million years levels had gently oscillated between 180 and 280 as the Earth steadily cooled and warmed in cycles. By 1953, when a postdoctoral researcher at Caltech called Charles Keeling started making measurements of the atmospheric concentration of carbon dioxide across the US, that number had reached 310ppm. Now, 60 years on, the numbers are going up and up. "It is obvious levels will keep on climbing rapidly until, or if, serious



➔ action is taken,” says Paul Pearson, a climate scientist at Cardiff University. “We could be approaching 1,000ppm by the end of the century.”

In 1958, Keeling set up his instruments at their permanent location, Mauna Loa, and started plotting what is now referred to as the Keeling Curve, a graph tracking CO₂ levels. The curve has risen steadily ever since, with small fluctuations each year relating to the seasons. Carbon dioxide levels peak in May, when the northern hemisphere plants and leaves that degraded over the winter have released all their carbon dioxide, and just before the newly formed leaves start to use some of it up again. This year, after 13 May's record 400.17ppm, the levels soon dropped back below 400ppm, leaving the monthly average at 399.76ppm. But inevitably, in the coming years that



Geoscientist Richard Norris holds the cast of a skull of a walrus from the Pliocene epoch, which was host to a menagerie of exotic animals now extinct

monthly, and eventually yearly average will sneak up to over 400ppm.

In an attempt to figure out how the planet will react to 400ppm carbon dioxide, climate scientists need to explore the distant past. There isn't yet agreement on exactly when levels of CO₂ were last this high, but one contender is the Pliocene: between 2.5 and 5.5 million years ago. Bang in the middle of the Pliocene, around 3.5 million years ago, CO₂ levels could have reached 400ppm.

By unpicking what the Pliocene Earth was like, we might get a glimpse of what the future holds for humankind if we keep on belching out carbon dioxide.

WARMER WILDS

Back then our world was very different. It was much warmer; temperatures were on average 3° higher. In places, especially the Arctic regions, the temperature could have been almost 10° higher. Sea levels were at least 15m higher. Dappled sunlight was peaking through the treetops of forests that thrived on what is now the frozen Arctic tundra. Creatures like glyptodonts, giant armadillo-like animals, and sparassodonts, a type of carnivore with huge fangs like a sabre-toothed cat, roamed the planet.

Richard Norris, a geoscientist at Scripps Institution of Oceanography in La Jolla, California says that this warmer world would see more rainfall at mid-latitudes, more monsoons and fewer deserts in Africa. “The world was somewhat familiar, but the way rainfall and climate worked was not the same as now,” Norris says.

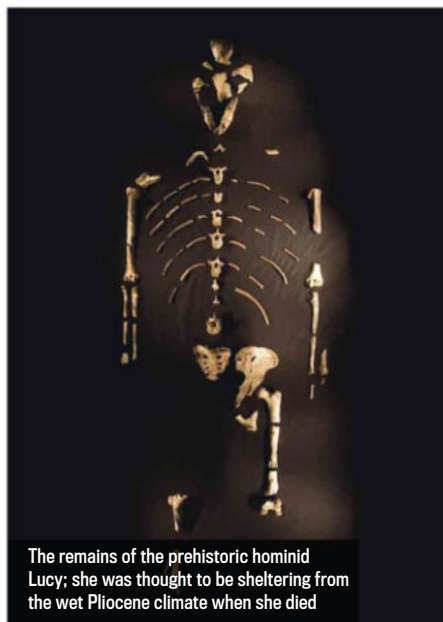
Some of our ancestors lived in this wet, balmy climate. ‘Lucy’, a female *Australopithecus afarensis* whose skeleton was discovered in Ethiopia in the 1970s, was an early hominid, and was perhaps finding shelter from the rain in Africa 3.2 million years ago.

But how do we know that carbon dioxide is implicated in this different climate and weather? We have a pretty detailed knowledge of carbon dioxide levels going back almost 1 million years, thanks to tiny bubbles of air trapped in ice-cores drilled from Antarctic ice, some 3.6km (2.2 miles) deep. But to find out how much carbon dioxide was around during the Pliocene and beyond takes a different approach – second-hand information known as proxy data.

Fossilised leaves give us some clues. Leaves have tiny holes called stomata that let carbon dioxide in (so they can photosynthesise) and let water out. Being adaptable as plants are, the leaves can alter the number and size of stomata



Human ancestors like *Australopithecus afarensis* were wandering the Earth during the Pliocene, but they weren't responsible for high carbon dioxide levels present at the time, thought to be the result of increased volcanic activity



The remains of the prehistoric hominid Lucy; she was thought to be sheltering from the wet Pliocene climate when she died



Richard Norris (left) examines sediment samples off the coast of Newfoundland; fossils within can give an idea of ancient climates

WASTE
WATER
3%COMMERCIAL
AND RESIDENTIAL
BUILDINGS
8%TRANSPORTATION
13%ENERGY
SUPPLY
26%

THE BIG SOURCES OF CO₂

AGRICULTURE
14%LAND USE
AND FORESTRY
17%INDUSTRY
19%

Energy supply

The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions.

Industry

Emissions from industry primarily

involve fossil fuels burned on-site at facilities for energy. This sector also includes emissions from chemical, metallurgical, and mineral transformation processes not associated with energy consumption.

Land use and forestry

Greenhouse gas emissions from this sector primarily include carbon dioxide emissions from deforestation, land clearing for agriculture, and fires or decay of peat soils. However,

estimates indicate that on a global scale, ecosystems on land remove about twice as much CO₂ as is released by deforestation.

Agriculture

Emissions from agriculture mostly come from the

management of agricultural soils, livestock, rice production, and biomass burning.

Transport

Almost all (95%) of the world's transportation energy comes from petroleum-based

fossil fuels, largely gasoline and diesel.

Commercial and residential buildings

Greenhouse gas emissions from this sector arise from on-site energy generation and burning fuels for

heat in buildings or cooking in homes.

Waste and wastewater

Landfill methane forms the largest source of emissions in this sector, followed by wastewater methane and nitrous oxide.

THE KEELING CURVE: TRACKING CO₂



Charles Keeling's first measurements in 1958 revealed that for every million molecules of air, 315 of them were CO₂

THE SLOPES OF a volcano in Hawaii are home to the world's longest-running carbon dioxide measuring station. At Mauna Lao, in 1958, Charles Keeling set up his air-sampling equipment. Mauna Loa is perfectly placed to get a good reading of what's in the air. It's sufficiently high (3,396m above sea level) that fluctuations in carbon dioxide levels, caused

by plants photosynthesising or the ocean taking up carbon dioxide, are averaged out.

A graph called the Keeling curve, which shows how carbon dioxide levels have changed since 1958, is Keeling's major legacy. Another is the network of monitoring instruments that continues what Keeling started. His son, Ralph Keeling, runs the

Mauna Loa instrument today. The general trend seen from the Keeling curve is consistently rising CO₂. Each year the levels go up and down. These fluctuations are caused by the seasons, and are dominated by what is happening in the northern hemisphere – the part of the planet with most plants.

"If Earth suddenly became Pliocene-like, the sea-level rise alone would wipe out many major cities"



➔ to cope with different atmospheric conditions. By measuring the size and density of stomata in fossilised leaves, scientists can work out how much carbon dioxide that tree was dealing with when it was alive, helped by comparing with leaves grown in controlled conditions in greenhouses.

The oceans provide other clues. Chemical processes in the ocean are recorded in tiny fossils and shells that sit in the sediment on the sea floor. Like an ice core, a sediment sample can tell

us what pollens were around when the sediment was laid down – which in turn offers clues to the temperature at that time. Carefully analysing the chemical composition of fossilised shells can reveal information about the acidity of the ocean at the time those shellfish were growing, and the carbon dioxide levels at that time.

Put all this proxy data together, and the warm, wet Pliocene atmosphere is revealed to have been one with lots of carbon dioxide – at least in the high 300ppm region, and possibly over 400ppm at times. It's not entirely clear why the Pliocene had such high carbon dioxide levels, but one source can definitely be ruled out: Lucy wasn't to blame. "It wasn't because of people," says Dan Lunt, a climate modeller from Bristol University. One idea is that there was more volcanic activity, so more carbon dioxide being emitted. Concurrently, there was possibly less weathering – the natural processes that remove CO₂ from the atmosphere. Another theory is that changes in ocean circulation were responsible for releasing more CO₂. In truth, "Nobody really knows," says Lunt.

Even if we did know, working out what it was like in the Pliocene won't help predict what humans are facing in the next 100 years. If Earth suddenly became Pliocene-like, the sea-level rise alone would wipe out many major cities, all perched precariously on the continents' coastlines. "It's Armageddon," says Lunt. But that kind of sudden change isn't likely – Earth's processes move on a slower timescale.

Rather, the Pliocene is better thought of as representing what Earth would look like



We're pumping out so much carbon dioxide that the atmosphere is resembling that from previous geological eras

If we suddenly found that the climate had taken on all the effects of the Pliocene epoch, major cities like London would be underwater



once it has come to equilibrium, a steady 400ppm. The processes that led to the Pliocene's warm climate would have happened over many thousands, possibly millions of years. Humans have changed the climate by a similar degree in just a couple of centuries – an unprecedented shift. "There is nowhere in the whole history of the world, of geology, where we know there have been changes as rapid as those we're making now," says Lunt.

Equally, the timescales in the Pliocene make it useless for predicting the consequences of acidifying the oceans today. All the carbon dioxide we're emitting is dissolving and forming carbonic acid at the ocean surface. In the Pliocene, carbon dioxide changes were slower, and the oceans had time to respond without becoming acidified, says Norris. "If you slowly add CO₂ to the ocean, it mixes in so you don't acidify the surface," he says.

BACK TO THE FUTURE

Some climate researchers think other epochs might better mimic a time when the Earth's carbon dioxide levels reached 400ppm. Pearson thinks that the last time the Earth experienced 400ppm carbon dioxide was the Oligocene, around 25 million years ago.

Back then, it was somewhat warmer than the Pliocene. The climate varied a lot, so there's no such thing as a typical Oligocene climate. Most likely, at times Antarctica was fully glaciated, and other times it wasn't, Pearson says. The only ice in the northern hemisphere was seasonal sea ice and sea levels rose and fell significantly, but probably averaged 40-50m higher than today. "Although

we cannot be sure that CO₂ was the only cause of this, the past gives us very little comfort that 400ppm is a safe level," Pearson says.

But all this could be immaterial. Soon we will surpass 400ppm. As levels rise, we need to look yet further back in time to see what we're in for. There are hints in the carbon dioxide record that some 56 million years ago, a time called the Palaeocene-Eocene Thermal Maximum, large and sudden spikes in carbon dioxide were seen, says Norris. Although 'sudden' means thousands or tens of thousands of years, this period might have a closer relationship to the likely future than the Pliocene or Oligocene, Norris says.

The worry isn't that humanity can't survive in Pliocene-like conditions, Norris says. The problem is surviving the violent changes that our planet is being forced to make before it can settle into a new regime. Pearson thinks we've already gone much too far. "We must get CO₂ down below 350ppm as soon as we can," he says, "and that means leaving most of the remaining fossil fuels in the ground." ■

KATHARINE SANDERSON is a science journalist and former features editor for *Chemistry World*

Find out more

BBC
RADIO



Listen to *In Our Time - Climate Change* on BBC Radio 4. Melvyn Bragg discusses the science behind rising global temperatures and whether we're already too late to avert catastrophe.
<http://tinyurl.com/p2d8bzb>

550-1,000

is the estimated CO₂ levels in ppm by 2100. Levels of 1,000ppm have not been seen since the Palaeocene-Eocene Thermal Maximum, 56 million years ago. SOURCE: Intergovernmental Panel on Climate Change

170,000

years: the length of time that the Earth experienced global warming during the Palaeocene-Eocene Thermal Maximum after this huge outpouring of carbon dioxide.

SOURCE: Department of Global Ecology, Carnegie Institution for Science

70

per cent is the immediate cuts in carbon dioxide emissions needed to keep the amount of the gas in our atmosphere stable at current levels.

SOURCE: realclimate.org

2

metres is the sea-level rise per degree rise in temperature that is now inevitable over the next 2,000 years. The prediction for 2100, if emissions remain the same as today, is a temperature rise of 4 or 5°.

SOURCE: Proceedings of the National Academy of Sciences of the USA

We have the technology



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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



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Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

Q JACOB BIRD, BRIGHTON

What will happen to Voyager 1 now?

A IN SEPTEMBER, NASA announced that its Voyager 1 spacecraft had entered interstellar space, becoming the first human-made object to travel beyond the heliosphere – the bubble of charged particles surrounding the Sun.

Although Voyager 1 has left our planetary neighbourhood, it's still well within the Sun's gravitational grasp. Some scientists maintain that the Solar System extends all the way out to the Oort cloud – a vast reservoir of comets that are loosely bound to the Sun. The spacecraft is expected to take roughly 300 years to reach the inner edge of the Oort cloud, and some 30,000 years to pass through.

The spacecraft's radioactive power source will keep its instruments going until at least 2020, at which point NASA will start turning them off one by one. With its systems shut down, Voyager 1 will become a silent ambassador orbiting the centre of the Milky Way. In 40,000 years' time it'll be closer to another star (AC +79 3888) than our own Sun. But with no way of contacting Earth, this'll be one milestone that Voyager 1 celebrates on its own. **RM**



Voyager 1 could survive for billions of years and possibly outlast the human race

PHOTO: NASA

In Numbers

200bn

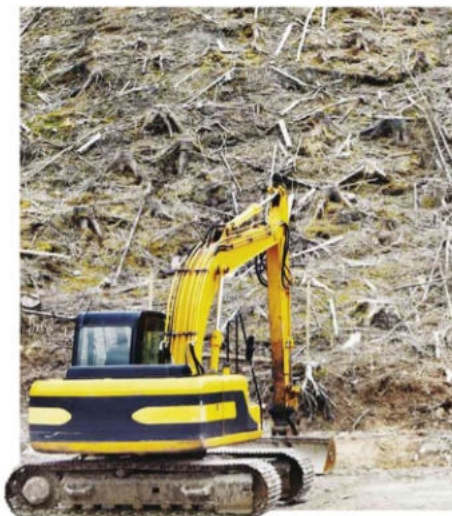
is the number of 'rogue planets' thought to be in our Galaxy. These are planets that roam space on their own, without orbiting a star.

Q RICHARD O'NEILL, GLASGOW

What would happen to the weather if we chopped down all the trees?

A IN THE UK, there are about 150 million tonnes of carbon locked up in trees. Cutting them down and burning them would result in roughly the same amount of CO₂ that the UK emits in a year. Deforestation globally currently contributes about 15 per cent of greenhouse gas emissions.

Trees play an important role in taking water from the ground and releasing it into the atmosphere. Without trees, more rainwater would stay locked underground, or run off into the sea, reducing the amount of evaporation from the land. The soil erosion that occurs without tree roots to stabilise the ground would also lead to an expansion of the desert regions and overall, the climate would probably become windier, warmer and drier. The exact effect on the local climate in the UK could be hard to predict though. If weather systems like the Gulf Stream were disrupted, Britain could actually get much colder. **LV**



Chopping down trees leads to 15 per cent of the world's greenhouse gas emissions

Q LEO BASSOON, SALISBURY

What's the highest energy food?



In a nutshell, it's high-energy food...

A The Ultimate Breakfast Platter, from Burger King's menu in the US, has 1,450 calories and topped a recent poll that compared calories per dollar for 10 US fast-food chains.

However, for a single, unprocessed food it's hard to top the almond. They are often cited as one of the highest-energy single foodstuffs. A report by the

Institute of Food Technologists stated that foods with smaller particle sizes are absorbed better, so almond butter ought to have the most calories per hundred grammes. In fact, it's about the same as peanut butter at 620kcal/100g. Ordinary butter is slightly higher (740kcal/100g), but pure sunflower oil beats both at 900kcal/100g. **LV**

Q LUCY TUTTLE, LEEDS

Why do some drinks taste better when they are cold?

A A 1997 STUDY at the Yale School of Medicine found that the action of drinking is more thirst quenching than being rehydrated through a nasogastric tube. That's because the physical sensation of drinking tells the brain that you are rehydrating. That sensation is enhanced if the temperature of the drink is hotter or colder than your mouth and throat, because the temperature-sensing nerves are stimulated as well as the touch sensitive ones. Cold also suppresses our sense of sweetness and commercial drinks allow for this, so drinking them lukewarm makes them excessively sweet. **LV**



QUESTION OF THE MONTH

WINNER!

Congratulations to Alan Blackwood who wins a copy of *Discover The Savage World* (Miles Kelly, £20)



Nuclear waste has to be stored somewhere, making it a growing problem

Q ALAN BLACKWOOD, CHESHIRE

Why can't we bury nuclear waste in a subduction zone?

A SUBDUCTION ZONES occur where one vast slab of the Earth's crust slips below another and into the 2,000°C-plus regions below. As such, they sound ideal for disposal of radioactive waste, arguably the biggest problem facing the wider use of nuclear power.

The idea is beset by a host of problems, however. The most obvious is that suitable subduction zones would be far from any land, deep below the sea, and thus tricky to access reliably. In any case, such 'out of sight, out of mind' disposal at sea is currently banned. The law could be changed if a strong enough scientific case could be made, but

this is unlikely. Subduction zones are geologically highly unstable, and are the site of some of the world's most powerful earthquakes. This raises the possibility of the waste containers being damaged and driven back onto the sea-bed, rather than incinerated in the depths of the Earth.

These risks, along with the problems of simply getting to the dumping sites, have been assessed by scientists from nations faced with the problem of nuclear waste disposal, including the UK Committee on Radioactive Waste Management. And to date all have ruled out the idea. **RM**

Q LOUISE BRADLEY, ANDOVER

How does an anti-snore pillow work?



The anti-snoring pillow could be a boon for marital relations

A SNORING IS CAUSED by the soft palate vibrating as it partially blocks the airway. Anti-snoring pillows tilt the head backwards as you lie on your back. It's similar to the way that you tilt the patient's head during cardiopulmonary resuscitation (CPR), helping to hold the airway open. **LV**

Q BRIAN WINNARD, RAINHILL

How far into space have radio signals travelled?

A WE'VE BEEN BROADCASTING our existence on Earth into deep space via radio 'leakage' for around 100 years. Travelling at the speed of light, that encompasses a sphere 200 light-years across – and dozens of planetary systems. But any aliens will need receiving antennae hundreds of kilometers across to pick up the signals. **RM**



Let's hope that aliens don't get any ideas by tuning into *Independence Day*

TOP TEN

LONGEST BRIDGES



1. Danyang-Kunshan Grand Bridge

Length: 164,800m; Country: China



2. Tianjin Grand Bridge

Length: 113,700m; Country: China



3. Weinan Weihe Grand Bridge

Length: 79,732m; Country: China



4. Bang Na Expressway

Length: 54,000m; Country: Thailand



5. Beijing Grand Bridge

Length: 48,153m; Country: China



6. Lake Pontchartrain Causeway

Length: 38,442m; Country: USA



7. Manchac Swamp Bridge

Length: 36,710m; Country: USA



8. Yangcun Bridge

Length: 35,812m; Country: China



9. Hangzhou Bay Bridge

Length: 35,673m; Country: China

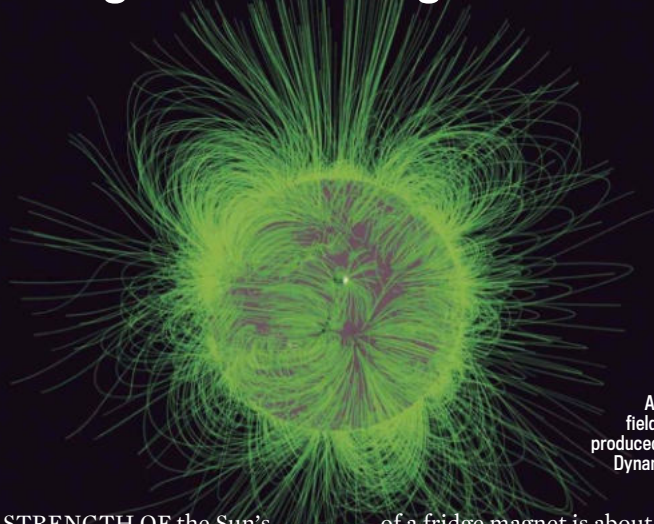


10. Runyang Bridge

Length: 35,660m; Country: China

Q TOM NEBBIT, LEICESTER

How strong is the Sun's magnetic field?



A map of magnetic fields around the Sun produced by NASA's Solar Dynamics Observatory

A THE STRENGTH OF the Sun's magnetic field (which can be measured in 'gauss') is very variable. But the most recent and accurate measurements have shown that typical magnetic fields just above the solar surface lie between 2 gauss and 6 gauss. By way of comparison, the Earth's magnetic field at the surface ranges between 0.25 gauss and 0.65 gauss, about 1/10th that of the Sun's.

These are actually quite weak magnetic fields. The typical strength

of a fridge magnet is about 100 gauss, more than 10 times the Sun's average field strength. The magnet in a typical hi-fi loudspeaker is about 10,000 gauss while medical resonance imagers typically use magnets of about 30,000 gauss. The strongest known magnetic fields, around objects called 'magnetars' (a type of neutron star), can be as high as a quadrillion gauss. Such high magnetic fields would warp all the atoms in your body, killing you instantly! **AG**

Q GABRIELLE SMITH, BEDFORDSHIRE

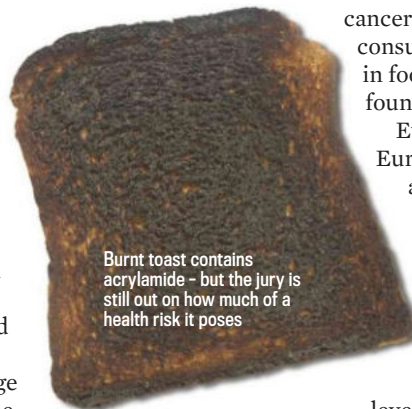
Can eating burnt toast cause cancer?

A IT'S LONG BEEN known that just over-heating, let alone burning, some foods can lead to the formation of compounds linked to cancer. These include heterocyclic amines and so-called polycyclic aromatic hydrocarbons (PAHs), which can lead to fried or smoked foods posing a health risk.

In the case of burnt toast, most concern surrounds the risk from the formation of acrylamide, a compound that has been linked to cancer and nerve damage in animals. That said, the

evidence of a direct link between cancer and acrylamide in food consumed by humans is far from compelling. While some studies have pointed to a doubling in risk of ovarian and uterine cancer among women consuming this compound in food, other studies have found nothing.

Even so, in 2007, the European Union's health advisors decided to take a precautionary approach, and recommended that people avoid eating burnt toast or golden-brown chips as they may contain unacceptably high levels of acrylamide. **RM**



Burnt toast contains acrylamide - but the jury is still out on how much of a health risk it poses

Q ANDREW EVERSETT, DEVON

What is a black box recorder made of?

A LET'S START BY dispelling one myth. Flight data recorders are not black, but coloured bright orange so that they can be found easily after an aviation accident. Aircraft carry two black boxes. The flight data recorder continuously logs details like the plane's speed, altitude, time of day and engine parameters. The other unit records the pilots' voices in the cockpit.

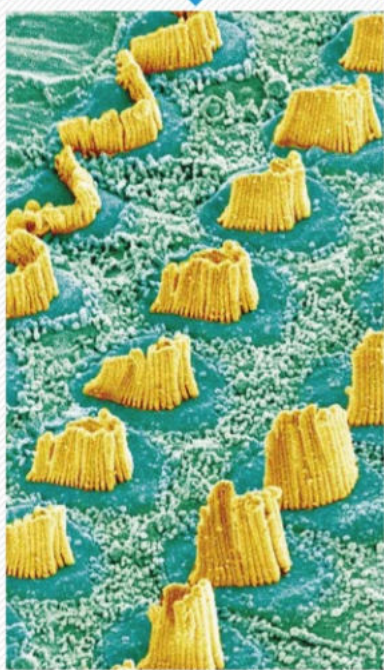
The units need to be resistant to fire and water and able to cope with the force of a major impact. They also need to withstand low air pressures at altitude should the aircraft suffer a sudden decompression. Likewise the recorder should be capable of bearing the crushing pressures down on the seafloor should the aircraft plunge into the ocean.



The 'black box' of an aircraft is built to be virtually indestructible

As a result, black boxes require very strong casings. Earlier models were simply made from stainless steel, but now housings also incorporate titanium, as well as an inner layer of heat-resistant material. **GM**

WHAT IS THIS?



KNOW THE ANSWER?

Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Dulcie Phipps correctly guessed fluorescing honeycomb coral

Q TIM REDGOOD, ASHFORD

At what distance does Earth no longer pull on an object?



You can never escape the clutches of Earth's gravity

A STRICTLY SPEAKING, THE Earth's gravity will always pull on an object, no matter how distant. Gravity is a force that obeys an 'inverse square law'. So, for example, put an object twice as far away and it will feel a quarter of the force. Put it four times further away and it will feel one-sixteenth the force. But, however far away the object is, it will always feel the pull of gravity, even though it might be vanishingly small. **AG**

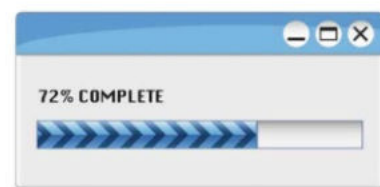
Did you know?

The fastest camera takes images with an exposure of 1.7 trillionths of a second and is able to show the movement of light.



Q SIMON JOHNSON, BRIGHTON

How many photos are uploaded every day?



A MORE PHOTOS ARE uploaded to Facebook daily than any other website. Facebook's latest figures report that it uploaded an average of 350 million photos per day in the fourth quarter of 2012. That dwarfs even specialist photo sharing sites like Flickr, which hosts over 8 billion pictures, about the same amount that Facebook uploads every 23 days. **GM**

Q JOE ANDREYEV, LONDON

Why do bags form under our eyes?

A THERE HASN'T BEEN much research to establish whether it's caused by a lack of sleep or something else. The skin under our eyes is very thin and fluid retention there can cause it to sag. It's possible that when we sleep this fluid has a chance to drain away, but diet may also play a part. Staying up late is often associated with drinking alcohol or coffee or eating salty junk food. Any of these could be the real cause of eye bags; we don't really know for sure. **LV**

Don't go out drinking; stay in with the latest *Focus* to avoid bags under your eyes





The Monarch butterfly travels for thousands of kilometres, a journey that takes three or four generations of the insect

HARRY ALLAN, BY EMAIL

How do some butterflies know where to migrate?

BUTTERFLIES KNOW BY instinct. As extraordinary as this seems, they are able to travel thousands of kilometres to find food, warmth or a mate, without ever having made the journey before or having any opportunity to learn the route.

The famous Monarchs migrate annually between Mexico and Canada, each generation continuing the journey begun by their parents. So their ability to find the correct route north in summer and south in winter must be inherited. The Painted Lady, weighing less than a gramme, takes up to six generations to complete a 14,400km (9,000 mile) round trip from tropical Africa to the Arctic Circle, passing through Britain on the way. By way of comparison, many birds and mammals make the same journey many times in their lifetime. So migrating species may learn the way from travelling in flocks or herds and from learning geographical features of mountains. **SB**

In Numbers

10,000

years is the age of ancient rock etchings found in Arizona, which have been confirmed as the oldest recorded petroglyphs (rock engravings).

DARREN GOODSELL, HASTINGS

Why do people like winning so much?

BECAUSE, LIKE OTHER animals, we evolved through competition and natural selection. Early humans who had a strong desire to outcompete everyone else might have found better quality food or more desirable mates and so passed on their desire to win.

In most societies men are more competitive than women, and this sex difference is seen as early as three years old. But there are some societies, such as the matriarchal Khasi of northeast India, in which women have more power and reveal greater competitiveness. Although the nature of winning has changed, the desire to show off, to be the best, or to belong to the top team, remains deeply



The greatest British athlete ever? Mo Farah knows what it's like to win

embedded in human nature. Sadly, this desire does not necessarily make us happy. Losing is distressing and painful, but so can winning, and the stress of modern high-performance sports can lead to both mental and physical illness. **SB**

ALAN HUGHES-HALLETT, WANSTROW

What are the fastest spreading viruses?

Doctors pictured with protective clothing at a Spanish influenza treatment centre in 1918



VERY AGGRESSIVE VIRUSES like Ebola don't spread far because they kill their human hosts too quickly. HIV is much more widespread because of its long incubation period. There are about 34 million people currently infected with HIV, and 7,000 more are infected every day. Dengue fever, a mosquito-borne disease, far outstrips this with 50 million people infected each year.

But the fastest spreading virus ever was the influenza virus responsible for the 1918 pandemic. That infected 500 million people and killed at least 3 per cent of the world's population. The worst SARS (Severe Acute Respiratory Syndrome) outbreak of 2002-2003 only infected 8,273 people, primarily in Asia. About 9 per cent of people infected with the virus died. **LV**



HOW IT WORKS

THE ROAD-CHARGED ELECTRIC BUS

ELECTRIC BUSES THAT charge up as they drive along have been introduced in South Korea. A new fleet of electric buses in the city of Gumi make electric buses more efficient because they don't have to spend hours stationary and out of service.

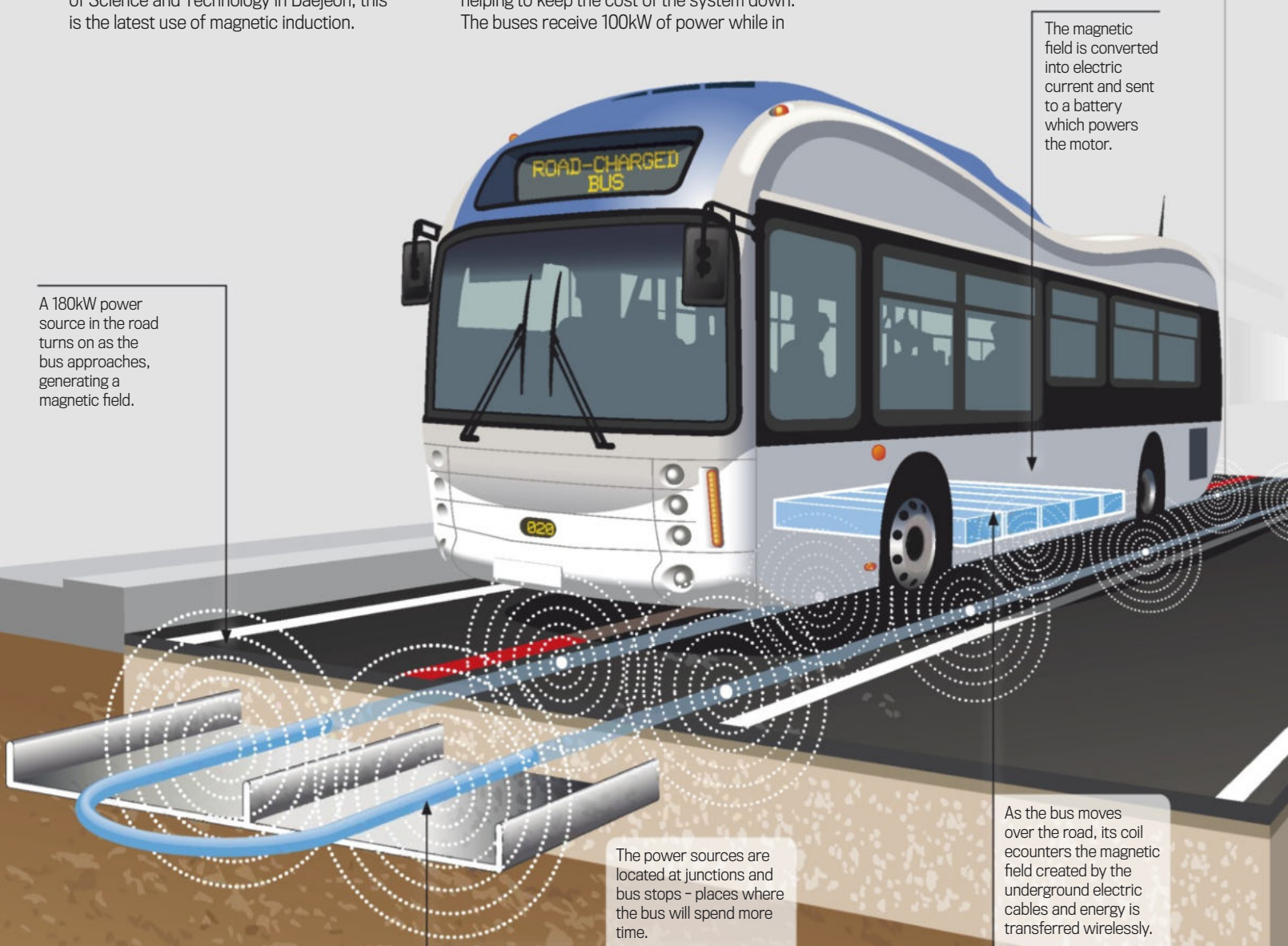
The two buses, which run on an inner city commuter route, receive power from underground coils built into the road. Developed at the Korea Advanced Institute of Science and Technology in Daejeon, this is the latest use of magnetic induction.

As current flows through the underground coil, a magnetic field is created. This field then induces a corresponding field in a secondary coil, located on the bus. This allows current to flow between the two, charging the battery. It's the same technology that is used in wireless mobile phone charging mats.

The process is surprisingly efficient, so much so that only 5-15 per cent of the road along the bus's route would need the coils, helping to keep the cost of the system down. The buses receive 100kW of power while in

motion, which is much more than can be delivered by a wireless charging station that you would use to charge a car in your garage – usually around 6.6kW.

By installing coils in areas that the buses typically linger, such as at traffic lights and bus stops, the vehicles can be charged even more efficiently.



THE NIGHT SKY: WHAT CAN I SEE IN NOVEMBER?



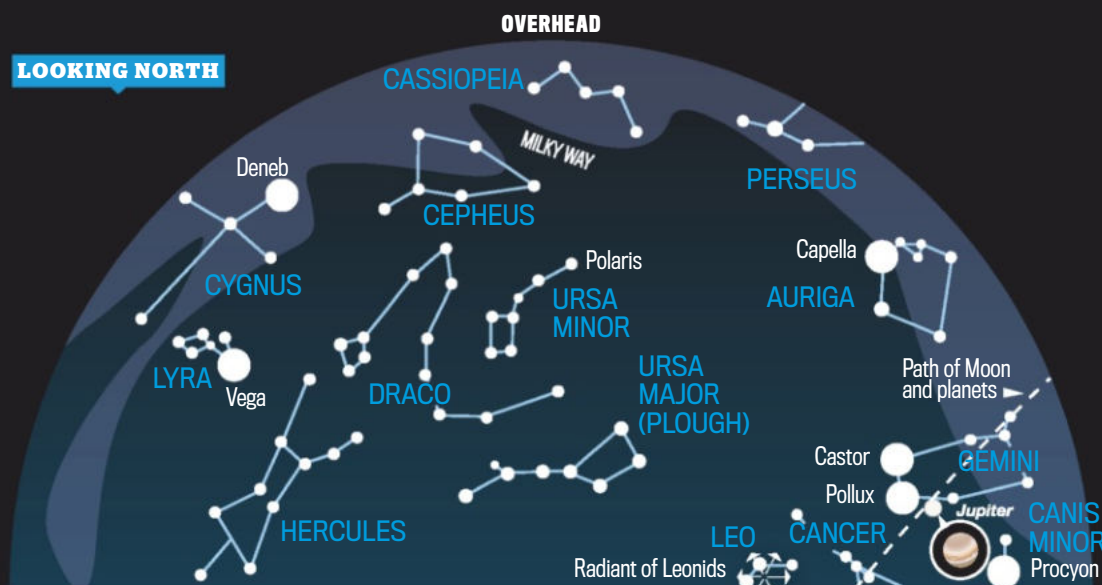
Don't miss *The Sky At Night* on BBC One every month
www.bbc.co.uk/skyatnight

Astronomy with
 Heather Couper
 and Nigel Henbest



THIS IS THE month when astronomers had hoped to witness 'the comet of the century'. Comet ISON will swing past the Sun on 28 November, and early predictions suggested it would shine as brightly as the Moon – and even be visible in broad daylight. But as the comet rushed headlong into the inner Solar System, its brightness has fallen well below the optimistic predictions. The comet will be there – but you may have to look quite carefully to spot it.

LOOKING NORTH



W

THE SKY AT 11PM (BST) IN MID-NOVEMBER 2013

LOOKING NORTH

17/18 November, best after midnight

It's the night of the annual Leonid Meteor Shower, which streams outwards from a point near brilliant Jupiter in the northeast. But this year, all but the brightest shooting stars will be drowned out by bright moonlight.

LOOKING SOUTH

1 November, 6pm

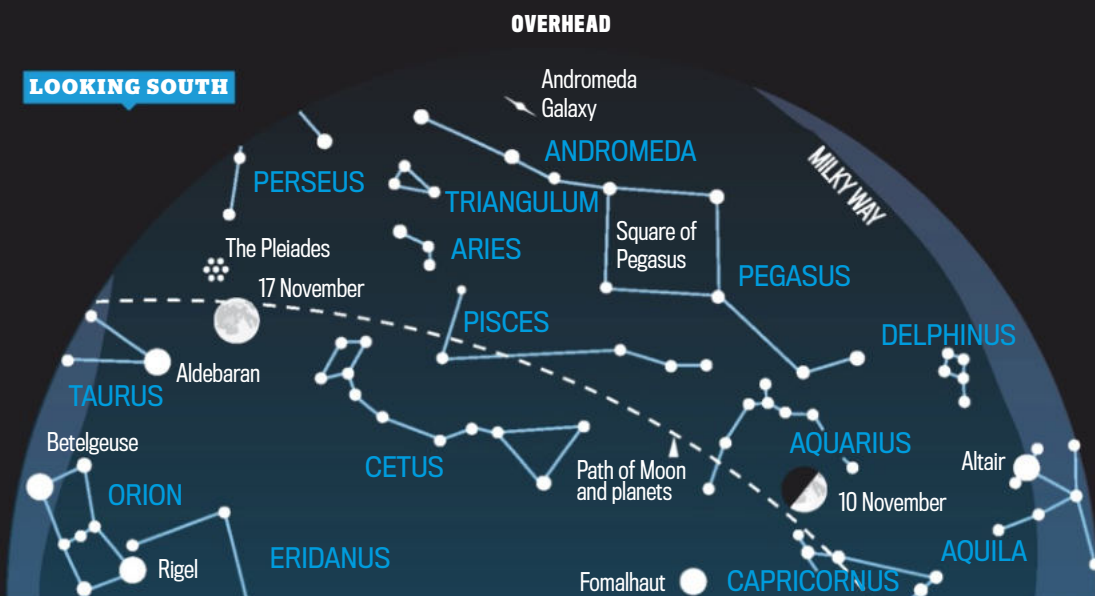
Venus is at eastern elongation – its greatest distance from the Sun. Spot it low in the southwest after sunset: a telescope shows the cloud-shrouded planet changing from half-lit to a crescent.

E

18 November, 6am

Mercury can be seen low in the southeast just before sunrise. On the morning of 26 November, it's very close to fainter Saturn.

LOOKING SOUTH



E

THE SKY AT 11PM (BST) IN MID-NOVEMBER 2013

W

Late November, early morning

The joker in the pack this month is Comet ISON. We hope it will be upstaging everything else in the morning sky, as it passes the bright star Spica on 18 November, and Mercury and Saturn on 24 and 25 November.

Find out more



Sky At Night Magazine
 On sale now,
 priced £4.99

Q MATTHEW RUMBLE, SOUTHAMPTON

Are humans the only species to commit suicide?

A IF WE DEFINE suicide as deliberately taking an action that will kill you, then there are plenty of examples. Bees will sting us even though it kills them; certain species of aphids will rupture themselves in a shower of sticky fluid that glues their body to a predatory ladybird larva – killing both. But these are examples of altruistic sacrifice to protect the colony. For it to count as suicide, the main motive of the animal should be simply to escape its own suffering, rather than to nobly assist some larger goal. That's almost impossible for us to determine.

Rats that are infected with the bacterium *Toxoplasma gondii* lose their fear of predators and so are more likely to be eaten by cats. The bacterium has evolved this effect because cats are its primary host and it benefits by ending up in a cat's intestine. To call the behaviour of an infected rat *suicidal* appears to stretch the definition, because the rat isn't acting entirely of its own free will. However, a 2013 study at Imperial College, London, found that there may also be a link between *T. gondii* infection in humans and schizophrenia. If we

accept that mentally ill humans can commit suicide, then why not rats?

Suicide can be difficult to distinguish from recklessness or accident, even in humans. But once we accept that some animals can suffer from depression and other mental illness, it seems reasonable to suppose that this could sometimes result in suicide. **LV**

Bees kill themselves when they sting you, but can it be called suicide?



Q GEORGE MCKENZIE, BY EMAIL

Is social networking changing the way our brains work?

A YES, AND IN many ways. In one study, researchers found that people with more Facebook friends had more grey matter in several important brain regions, although this might be because people who start with larger brains attract more friends. In another study, people who regularly used text messaging were asked to type strings of numbers. Although texting wasn't mentioned, they preferred the number strings that would spell a nice word on a phone. So without realising it we associate number strings with meanings and this affects the way we behave and feel.

Of course our brains change all the time, but there are good reasons to believe that social networking can have

profound effects. Our brains evolved when our ancestors lived in relatively small groups, probably no more than 150, and all interactions were face-to-face. To spend hours every day communicating fast and briefly with lots of people we cannot see needs a different kind of brain. Whether this is good, bad or just different remains very much an open question. **SB**



Social networks are expanding our minds

PHOTO: THINKSTOCK, ALAMY

Q SUSIE DAWSON, POOLE

Why do voices change as we age?

A FOR SEVERAL REASONS. During childhood our voices change gradually as the larynx (voice box) grows larger, making a stronger sound, and the vocal cords mature. Then in boys a dramatic change occurs with puberty as changing hormones affect the size and shape of the larynx and the voice 'breaks'.

Most voices then remain relatively stable for many decades until in later life our voice becomes weaker and more tremulous as our muscles begin to shrink, membranes thin, and fine control weakens. Men's voices tend to rise in pitch while women's voices drop.

Despite all these changes, though, our own voice can remain recognisable by our family and friends throughout a whole lifetime. **SB**

The rich tones of a seasoned choir are thanks to thinning membranes and weakening muscles



Q KATHERINE CORFIELD, OXFORD

Is it better to play the same lottery numbers?

A THE CHANCES OF winning the jackpot remain 1 in 14 million whether you stick with the same numbers or take the 'lucky dip' option, which uses a randomiser to create fresh numbers each time. But the lucky dip does stop you using common selections, and thus having to share the prize with many others. **RM**



Q HEPZI SAOIRSE-VILLAZON, DEVON

How do pineapples reproduce?

A EACH OF THE diamond-shaped scales on a pineapple is formed by a different flower. Up to 200 of them grow together in the middle of the plant. The fruits that each one produces swell and fuse together to form a pineapple.

Pineapples are pollinated by insects, hummingbirds and bats but they will produce fruit without being pollinated. In fact the seeds worsen the quality of the fruit, so commercial growers try to restrict pollination. Instead they are propagated using growths called 'suckers' that grow from the base, or by planting out the crown after it has been cut off the top of the pineapple. **LV**



A pineapple is actually lots of little fruit squashed together

Q ROSIE O'BRIEN, DURHAM

Which harbour more germs – touch screens or keyboards?



You'd better clean your keyboard if you don't want *E. coli* bacteria ruining your day

A IT'S BEEN DUBBED 'QWERTY tummy'. Yes, the bad news is that one of the most widespread bugs found on computer keyboards is *Staphylococcus aureus*, a bacterium that causes food poisoning. That and other harmful germs are transferred onto our keyboards after we have been to the loo, eaten lunch at our desk or picked our nose.

A study in 2008 found that some keyboards were dirtier than a toilet seat. The news is no better when it comes to the screens on our phones. Two years ago,

a study from the London School of Hygiene & Tropical Medicine and Queen Mary University of London, found that 92 per cent of phones harboured bacteria despite 95 per cent of users saying they washed their hands thoroughly. One in six handsets were contaminated with *Escherichia coli* bacteria, the type that leads to severe food poisoning.

Whether touch screens are grubbier than keyboards or vice versa is tricky to determine. Given that we tend to take our phones and tablets everywhere, sometimes even to the loo, I would say that touching transfers more toxins than typing. A pack of anti-bacterial hand wipes should do the trick. **GM**

NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/qanda

THE LATEST IN SOUND TECHNOLOGY

SCIENCE OF SOUND



Science of Sound
in association with
Q Acoustics

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- ▶ Monitor Audio
- ▶ B&O Play
- ▶ Astell&Kern
- ▶ Parrot
- ▶ Cyrus
- ▶ Damson

SCIENCE OF SOUND



Convert Ordinary to Extraordinary

People are spending an increasing amount of time listening to music stored on their computer. Often however, the experience is compromised, leaving music fans frustrated and dissatisfied with poor quality sound reproduction. Through an in-depth understanding of the science of digital-to-analogue conversion British hi-fi manufacturer, Naim Audio, has engineered an outstanding solution to the problem: the DAC-V1.

WHY CONVERT?

A digital music file must first be converted to an analogue signal for humans to experience it as sound. Your mobile device, PC or Mac will have its own DAC on board but it's usually of extremely limited capability. The DAC-V1 has been designed from the ground up to make the most of your music.

DIGITAL MADE MUSICAL

The DAC-V1 connects directly to your PC, Mac or laptop via a standard USB cable. It then takes the music signal and disregards the original timing from the source, which is infested with jitter or timing errors, and clocks it independently, preserving maximum fidelity. It then uses Naim's proprietary digital signal processing technology with 16 times oversampling and high quality digital filters to further refine the signal before it is converted to analogue.

EXTRAORDINARY QUALITY

You can listen through headphones such as the Focal Spirit Ones directly via its integrated Class-A headphone amplifier (another Naim innovation) or via Naim's NAP 100 power amplifier (pictured below) to loudspeakers. From the rock-solid build quality and bullet-proof materials, to the distinctive styling and engaging sound, these hand-crafted pieces of audio engineering redefine how music should be experienced in the home.



www.naimaudio.com





Find your QuietPoint®

The Audio-Technica ATH-ANC70 is the latest over-ear headphone from the award-winning active noise cancelling QuietPoint® range. Whether you fly a lot, work in a noisy office or simply love the stillness of a rare silent reprieve, QuietPoint® headphones give you a listening experience free from distractions.

The ATH-ANC70 provides up to 90% noise cancellation and offers a host of features including a mic and controller for answering calls and controlling your music.

The ATH-ANC70 has been designed to provide total long-wearing comfort and the earpads and headband are made from memory foam making them incredibly soft and comfortable to wear.

The ATH-ANC70 has a high quality microphone and controller discreetly built into one of the earcups. Simply press the illuminated Audio-Technica logo to activate the mic or to scroll through your music tracks.

The ANC70 will be available directly from Audio-Technica's online store (www.audiotechnicashop.com) from October 2013 as well as many good headphone retailers at a recommended retail price of £149.



audio-technica.

ONLINE STORE:
www.audiotechnicashop.com



Monitor Audio ASB-2

Monitor Audio's sleek new ASB-2 soundbar is the complete all-in-one home entertainment audio system. The beautifully engineered ASB-2 combines a high performance active audio system with the latest wireless streaming technologies to deliver a totally immersive home cinema, music and gaming experience. Simple to connect and effortless to use, the ASB-2 renders high quality home cinema sound directly from your television, set-top-box, Blu-ray/DVD/CD player and games console. It will also produce richly dynamic music from smartphones, tablets, laptops, PCs and NAS drives. Featuring Monitor Audio's own three-dimensional audio software, the ASB-2 will take you to a new world of sound.

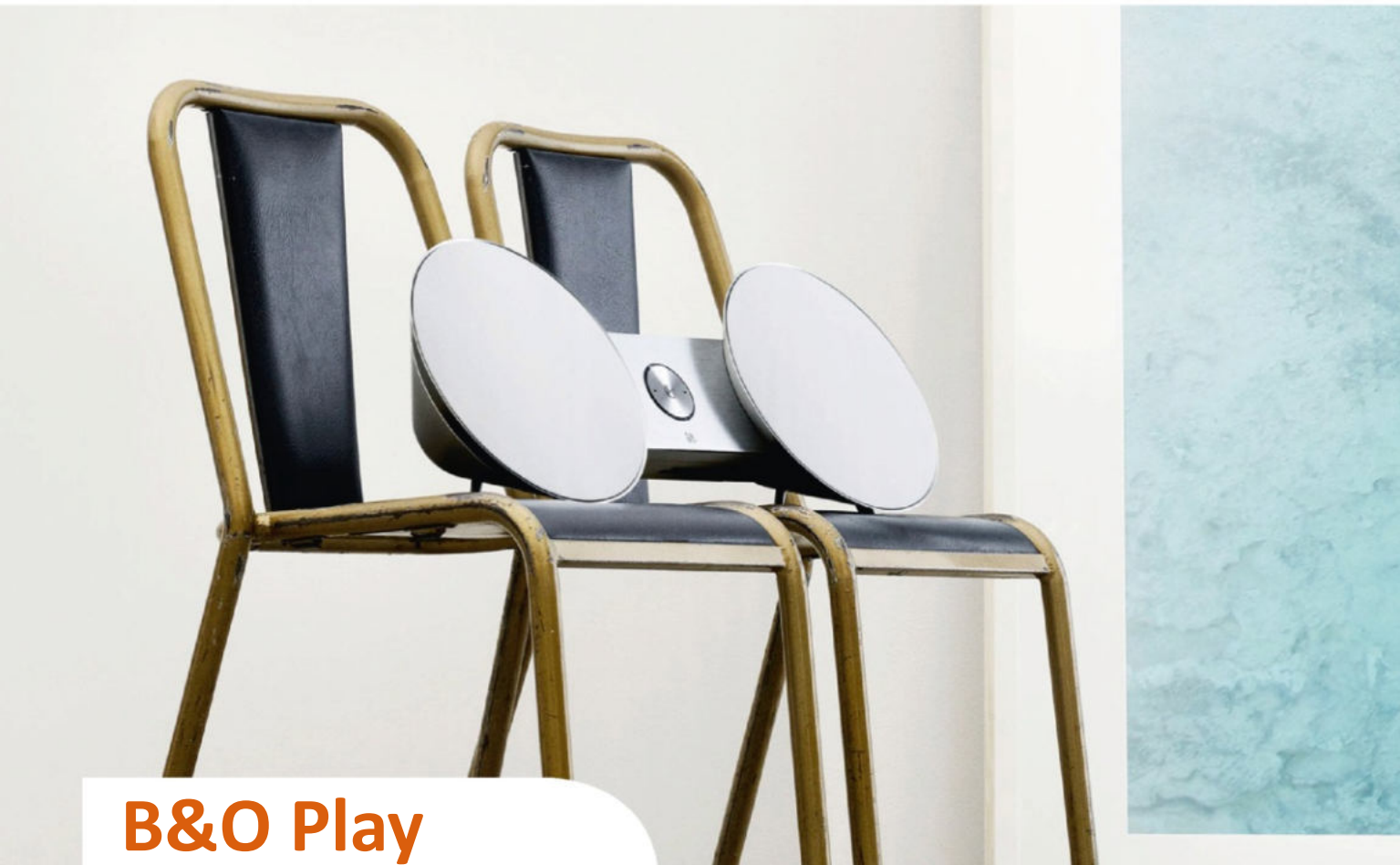
Monitor Audio has conceived the ASB-2 as the ultimate audio hub for the home. Apple AirPlay™, DLNA® and

UPnP enabled, the ASB-2 will deliver uncompressed music from files stored on PC or Mac, iPad, iPhone or iPod Touch, Android or Windows phone, or streamed from the internet. The Airplay Direct feature allows family and friends to connect and play directly to the ASB-2 without network access.

Finished in black grille cloth with solid brushed metal end trims, the ASB-2 is perfect for rack or cabinet top placement. Alternatively, it can be wall mounted using an optional wall fixing bracket, or a Sanus system. The ASB-2 is designed for those who love music and film, but loathe the clutter and complexity that comes with traditional home entertainment systems.

VISIT: www.monitoraudio.co.uk





B&O Play

The all-new BeoPlay A8 takes Bang & Olufsen's classic, David Lewis design and adds even more amazing technology. As well as seamless wireless music streaming from Apple devices via AirPlay, the BeoPlay A8 now supports streaming from all DNLA devices. The flexibility doesn't end there. So you always hear its powerful, polished tones at their best, the BeoPlay A8 will optimise its sound to best suit its surroundings – whether you're using it in free space or up against a wall. Adaptive Bass Linearisation also enhances your musical experience by protecting from extreme peaks.

Available in premium-quality black and white finishes, the BeoPlay A8 is a thoroughly modern marvel.



VISIT: John Lewis, Selfridges, and Sevenoaks

Astell&Kern

Astell&Kern's AK100 and AK120 use amazing audio engineering to put true hi-fi in your pocket. They can play any music file format, and support resolutions up to 24-bit/192kHz – well above CD quality (16-bit/44.1kHz). With studio-master quality music becoming more widely available to download, Astell&Kern offers the ultimate listening experience, on the move, at home or in the car. The players are beautifully built, inside and out. Top-grade internal components include industry-leading Wolfson DACs, while the brushed aluminium exterior, analogue-style control knob and intuitive touch-screen interface make the players a delight to hold and use. Capacity is easily expandable (up to 192GB) and the players can also be used as music-boosting external DACs in any system. They are also perfect partners for high-end headphones, which simply can't get the quality of performance they deserve from typical portable players or smartphones.

Contact:
Advanced
MP3 players **Astell&Kern**





Parrot Zik

Welcome to the world's most advanced wireless headphones. Designed by Philippe Starck and packed with the very latest technology, Parrot Zik is state-of-the-art audio you can wear – without trailing cables.

The Zik headphones use Bluetooth technology to wirelessly stream audio from smartphones, tablets and computers; pairing is quick and easy, aided by NFC connection capabilities. Smartphone users can enjoy hands-free phone calls, too.

Clever, active noise-cancellation means you hear your music, not noisy background environments – be that airplane engine noise or just the everyday clamour of your commute. It helps the clarity of phone calls, too, of course.

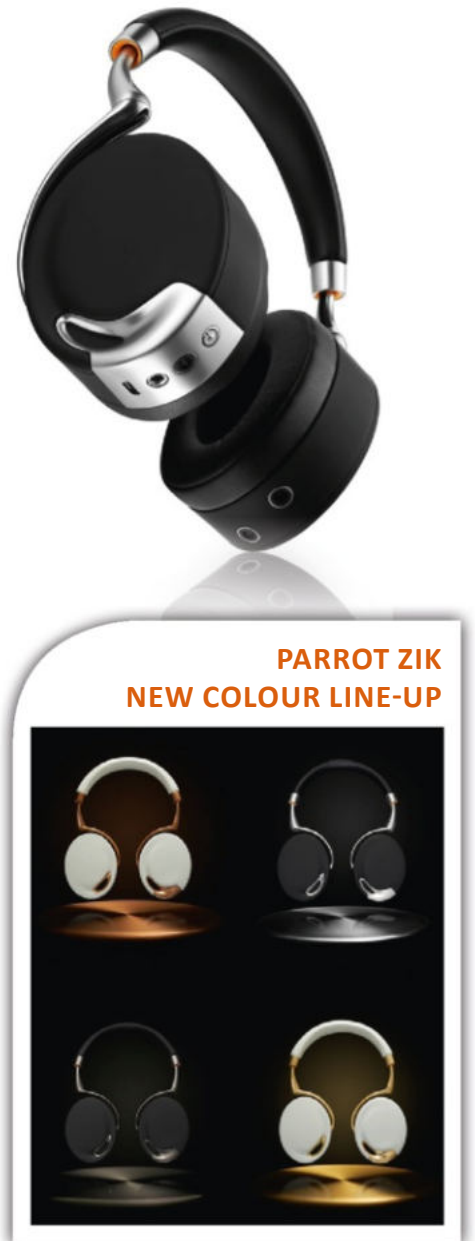
The Zik's Head Detection Sensor automatically pauses and restarts the music when you slip the headphones off/on again. In addition, you can control your music and

calls with a touch on the Zik's earcup.

Both these features mean you're not having to reach for your devices every time you want to pause a track, or change volume – you can do it all from your headphones.

A companion app – available for both Apple and Android devices – allows you to customise audio settings to suit your music, mood or surroundings, with Parrot's Concert Hall option to expand the boundaries of your sound.

Parrot Zik is now available in four colourways – including a gold-trim model that's a great match for the new gold Apple iPhone 5s. You can also accessorise your headphones with a travel-friendly carry case and keep the wireless music going for even longer with a spare Zik battery.



VISIT: Amazon and Apple Store



design by **S+ARCK®**

Parrot
Zik

Cyrus

Cyrus has been engineering high end hi-fi products for thirty years. In that time, they have become well known for pushing the boundaries of hi-fi design with their technological innovations, and creating products which recreate studio quality music with fantastic results.

STREAMING SYSTEM

Welcome to high definition music streaming. Once you experience it, you can never go back. Using this ultimate streaming hi-fi system, you can close your eyes and imagine the band is performing in your living room. Every track is transformed into an exclusive live show.

- **Stream X₂** – dedicated music streamer which can't be rivalled for sound quality. Wirelessly play your own music or choose from thousands of internet radio stations.
- **DAC XP Signature** – converts the numbers from the Stream X₂ into the music your speakers understand, upsampling all sources to the highest 32-bit resolution to add the incredible sound quality Cyrus is known for to everything you listen to.
- **PSX-R** – off board power supply which gives the DAC XP Signature some extra oomph, producing an audibly fuller sound.
- **Two Mono X 300 Signatures** – amplify your music with breathtaking clarity, using Cyrus's unique Zero Feedback technology to make sure nothing is added to or taken away from the notes of your favourite song.

STREAMLINE₂

Complete studio quality streaming solution. The Streamline₂ brings a world of high quality music to your fingertips. Access your entire music collection or thousands of internet radio stations at the press of a button (or a tap of our Cadence, iOS app), and uncover depths and details you didn't even know existed within your music.



MAIN IMAGE: STREAMING SYSTEM, BELOW: STREAMLINE₂



FIND OUT MORE ABOUT HIGH
QUALITY STREAMING:
www.cyrusaudio.com/streaming
@cyrus_audio ; facebook.com/CyrusAudio

CYRUS
ENGINEERED TO ENTERTAIN



Damson Jet

The all-new Damson Jet adds a new dimension to one of tech's fastest-growing product categories – the versatile, portable, wireless Bluetooth speaker.

Jet is the result of Damson's extensive work with the people behind the Bluetooth standard. Together they've created the world's first portable wireless 'real stereo' speaker pack.

Sold exclusively in pairs, Jet takes the stereo signal from your smartphone or tablet, then the two speakers calibrate with one another to allow for the exact distance between them (banishing any time lag). This creates real stereo sound from speakers so small they can fit in the palm of your hand!

Compact, curvaceous and colourful, Jet is the wireless all-rounder that uses cutting-edge, state-of-the-art design to fulfil all the needs of today's passionate and mobile music fan. High quality Apt-x Bluetooth and NFC-compatibility ensure both performance and convenience are top-rate, while a range of vivid colour finishes ensure Jet hits exactly the right design note in your lounge.

Ask yourself: in the rush to wireless convenience, what was sacrificed that didn't need to be? 'Real stereo sound' is the answer – and Jet is the solution. Jet puts the true sound of your favourite recordings back on the agenda, and in a compact, portable and ultra-contemporary wireless package. Damson Jet: £149.99 (pair)



VISIT: www.damsonaudio.com





Q Acoustics Q-BT3

The new Q Acoustics 'Q-BT3' is a brilliant audio solution for nearly every requirement. Appearance-wise it looks just like a pair of small, neat and stylish hi-fi loudspeakers; but bringing your smartphone into the mix and wirelessly stream Bluetooth signals to the Q-BT3, transforms it into a super quality modern hi-fi 'mini system'.

Connect it to the audio output of a television or set-top box and the Q-BT3 comfortably outperforms typical soundbars. For movie lovers wishing to 'feel the Earth move', there's a separate subwoofer output to connect your subwoofer of choice. A second line level input allows you to connect a CD, DVD, Blu-ray player or any other 'line level' source.

Hidden within the Q-BT3 speakers is a high quality, 2 x 50 Watts per channel amplifier, a Bluetooth V4.0 wireless receiver (with advanced 'aptX' capability for improved sound quality), and a low distortion Digital to Analogue Converter (DAC), accessed via an optical input. In addition to the small, elegant, infrared remote control included, Q-BT3 can also be operated by the remote controls which come with many satellite and cable TV boxes (including UK Sky and Virgin models).

CONTACT:
www.qacoustics.co.uk/bt3
or phone: 0844 800 8528



ALIEN HUNTERS

With a new British project set to renew the search for an alien civilisation, **Paul Sutherland** asks if we'll soon be talking to ET

Accompanies
the upcoming
BBC TV series
Do Aliens Exist?

SETI – THE SEARCH for Extra-Terrestrial Intelligence – has so far proved fruitless. We've been listening to the stars for decades in the hope of making first contact, maybe even receive the odd starship blueprint or two, yet we've heard little more than the indifferent radio crackle of space.

Not ones to so easily give up are a group of British scientists, who are linking up in a fresh quest to find ET. Researchers in different fields have formed the UK SETI Research Network (UKSRN) to share expertise and ideas. It's an informal collaboration with no special funding yet – no surprise in these austere times. Its participants include language experts, astrobiologists, radio astronomers and *BBC Focus Magazine* columnist and sci-fi author Stephen Baxter. The Astronomer Royal, Lord Martin Rees, is the network's patron.



The Mullard Radio Astronomy Observatory, Cambridge, will be put to use hunting for aliens as part of the e-MERLIN network

PHOTO: NIGEL BLAKE

➔ It was two scientists at Cornell University in the US, Giuseppe Cocconi and Philip Morrison, who first proposed that astronomers tune in to nearby stars to listen for alien signals in 1959. The earliest search was Project Ozma in 1960, when radio astronomer Frank Drake pointed the Green Bank telescope in West Virginia at nearby Sun-like stars Tau Ceti and Epsilon Eridani. In 1984 the SETI Institute was established in California.

Methods of searching for ET include using giant optical telescopes to look for flashes or unusual transits of planets in front of other stars. But the method seen as most likely to succeed is still the traditional technique of listening with radio telescopes. And here the UK already has a powerful search instrument called e-MERLIN, which is made up of seven radio telescopes working together.

Since 1980, the seven, including Jodrell Bank's iconic Lovell Telescope, near Manchester, have operated together as a single telescope called MERLIN, which stands for the Multi-Element Radio Linked Interferometer Network. The other six are the Mark II telescope, also at Jodrell Bank, plus instruments at Cambridge, Defford, Knockin, Darnhall and Pickmere.

In March 2012, a 10-year, £25 million upgrade to this array of instruments spanning 217km (134 miles) of English countryside was completed, boosting its power. Leased phone lines linking the individual telescopes have been replaced by 690km (428 miles) of high-speed fibre-optic cables. They now collect as much data in a day as they did before in a year. By operating together over a long distance, e-MERLIN's telescopes can observe the Universe in similar detail to the Hubble Space Telescope.

"The dishes are the same, typically about 25m in diameter, but everything else has changed," says Professor Tim O'Brien, Associate Director of Jodrell Bank Observatory. "The electronic receivers on the telescopes, the way signals are brought back to Jodrell Bank, and the way they are combined using a new supercomputer have all changed."

AN ONGOING QUEST

Jodrell Bank has been used to try and pick up an alien signal before. "We took part in the Project Phoenix programme led by the SETI Institute from 1998 to 2003," says O'Brien. "The Lovell Telescope worked alongside Arecibo in Puerto Rico. For several weeks at a time we would look

"By operating together, e-MERLIN's telescopes can observe the Universe in similar detail to Hubble"

at about 1,000 relatively close stars, in a wide band of the microwave part of the radio spectrum."

Using two telescopes allowed the team to reject interference from local devices such as microwave ovens and mobile telephones. If a signal was detected in one telescope but not the other, they knew it was not real. Using the multiple telescopes of e-MERLIN will help sort spurious signals in the same way.

"Phoenix was a targeted search where we were looking at each star for a limited time," says O'Brien. "We had to hope that aliens had not just sent a signal for a short time since that would limit our chances of picking it up."



The Lovell Radio Telescope at Jodrell Bank forms the centrepiece of the e-MERLIN network



Britain's SETI network

A host of powerful radio telescopes that have been wired up across the UK will soon start the search for an alien race



PICKMERE



DARNHALL



KNOCKIN



LOVELL, JODRELL BANK



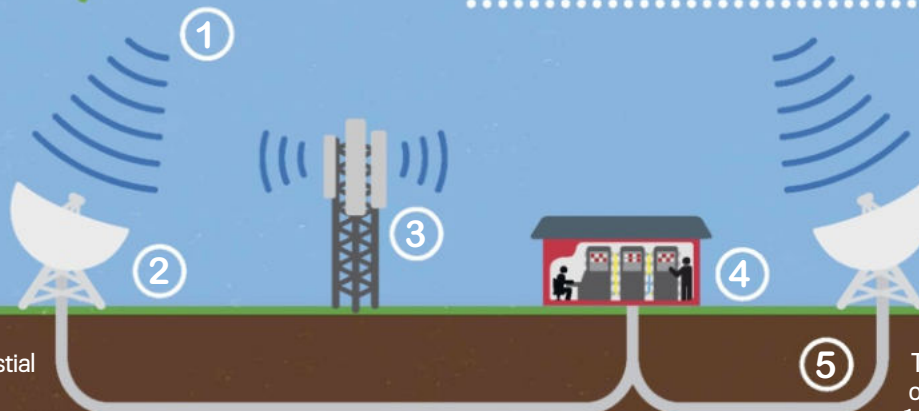
MK II, JODRELL BANK



CAMBRIDGE



DEFFORD



1 Although celestial objects can produce radio signals at well defined frequencies, such as the hydrogen 'line' at 1420.4MHz, natural processes such as turbulence give these features in the radio spectrum a characteristic width. Transmissions produced electronically can be made with a much narrower frequency spread and hence a deliberate signal, or beacon transmission, will stand out from natural sources.

2 Radiation from these objects reaches the Earth and is captured by the dishes of e-MERLIN's seven telescopes – two at Jodrell Bank, plus Cambridge, Defford, Knockin, Darnhall and Pickmere.

3 Arrays of telescopes such as e-MERLIN can distinguish between local signals – such as those from

mobile phones – and those from distant objects in space by the ways the signals are received by the widely separated telescopes.

4 A supercomputer at Jodrell Bank, called a correlator, combines the signals from the seven dishes after they pass along sections of 690km (428 miles) of fibre-optic cable.

The correlator carries out one Petaflop, or 1,000,000,000,000,000 operations per second.

In terms of operations per second it ranks among the fastest computers in the world.

5 Traffic along the new cables from the seven telescopes to e-MERLIN's correlator travels at a rate of 210Gb per second, which is around a fifth the total amount of internet data crossing the UK at any time.

FOR or AGAINST: WILL SETI FIND ALIENS?



Alan Penny, co-ordinator of the UK SETI Research Network



Who doesn't want to know whether or not we are alone? Contact with an advanced civilisation could mean great progress in medicine, technology, and many other fields. Also the search itself has spin-offs – data processing techniques, the teaching of science, and the inspiration from the fact that we ourselves are a bold, enquiring civilisation. But we don't know whether our searches could find them, or even if they are out there. One thing is certain. We will never know unless we look.



John Gribbin, author of *Alone In The Universe: Why Our Planet Is Unique*



Plenty of evidence suggests that life is common in the Universe – not least because complex molecules up to and possibly including amino acids have been detected in space. But technology-using intelligence? No. For a civilisation like ours to evolve, you need such things as a stable star, not too many asteroid impacts, and a large metallic core to generate protective magnetic shielding. That sort of combination is highly unlikely. So intelligent aliens will be rare.



Jocelyn Bell Burnell identified the first pulsar in 1967 after ruling out 'little green men'

Today's technology is far more powerful. The sort of specialised equipment that previously had to be fitted to receive or analyse a signal is now more standard in observatories. So a good part of the infrastructure is already in place.

A practical problem in gathering data with e-MERLIN is the sheer amount of it: the seven telescopes generate 42 terabytes (42,000GB) of raw data a day. So other options include saving occasional slices of data or developing software to process signals on the fly. "What we are doing is testing the capability of that system. The next step is to explore how best to analyse it," says O'Brien.

How the team will run a search for an alien signal around a busy science schedule is also still to be decided. "Obviously e-MERLIN has an approved science programme," says O'Brien. "For half its time it carries out large-scale projects that involve hundreds of astronomers from all over the world, ranging all the way from cosmology to gravitational lenses, supernova explosions and looking for the early stages of planet formation in the dusty discs around stars."

For the rest of the time e-MERLIN carries out research for astronomers who have applied for telescope time and been awarded it. So the UKSRN team may have to do a targeted programme like Phoenix and apply for telescope time.

An alternative method could be a 'serendipitous search', where the project effectively piggybacks on somebody else's observations. While an astronomer is using the telescope to do their own science, the data could simultaneously

be processed to look for signs of ET. "Such signals might typically be unnatural. They will look different from the signals that, say, a quasar astronomer would be interested in," says O'Brien.

LOST IN TRANSLATION

But what sort of signals might give away the aliens? If any extraterrestrials wanted their message to be heard or seen, they would surely make it look different to a natural signal so that you could identify what it was. "A natural signal is typically broad, as most astrophysical objects produce radiation across a wide range of wavelengths in the spectrum," O'Brien

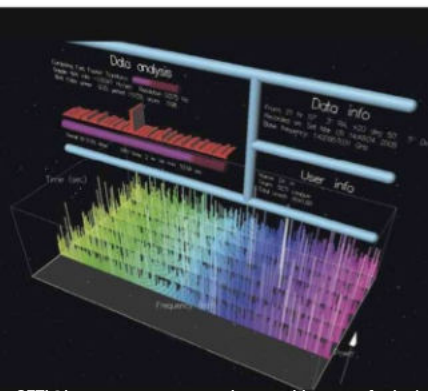
explains. "You do get some natural signals that are more distinct, the famous one being the hydrogen line produced by hydrogen atoms in the interstellar medium, but even those things have some width. With our own technology, humans produce much narrower signals with devices like mobile phones, microwave ovens and computers. So we could take a spectrum from space and analyse it at very high resolution to try to find similar narrow, sharp signals."

Another way of making a signal stick out is by varying it in time, flashing on or off. Such a signal would look unnatural. Indeed, the first pulsar, discovered in 1967, was initially dubbed LGM-1 (Little

JOIN IN THE HUNT

You can help in the search for intelligent aliens with your home computer

SINCE 1999, THE University of California at Berkeley has enlisted volunteers to help analyse radio signals from space. SETI@home, which is now in its second incarnation, works by harnessing the power of thousands of desktop computers around the world to mimic a supercomputer. It kicks in like a screensaver, when the computer is not otherwise being used, to examine chunks of data collected by the Arecibo telescope in Puerto Rico.



SETI@home presents you with a suitably scientific-looking feed of the radio signals you're analysing

The SETI@home program is available for PCs and Macs – full details can be found at <http://setiathome.berkeley.edu>

SPEAKING THE LINGO

UK SETI scientist Dr John Elliott of Leeds Metropolitan University asks how we'll understand an alien



“ SETI HAS ALWAYS been about listening out for evidence of alien technology, such as a beacon. It was really when I came aboard that we thought, what about language? If we do pick up an alien signal, what do we do with it and how can we identify its meaning? It's all to do with the structure.

If a message arrives in binary structure, as a string of zeros and ones like an intergalactic email, there will be a physical fingerprint of the pattern within it. I have looked at many languages and have ascertained that there is a universal underpinning structure to all languages that humans and even dolphins and other animals use.

If aliens do send us a deliberate message, then I hope they would have the foresight to include some sort of crib, a Rosetta stone, to help us break the code. Unless you have that to tell you that a particular sound or symbol means a particular thing then you are lost.

Certainly, we'd realise that it was a message, but to get to its constituent parts... well, it wouldn't be like the

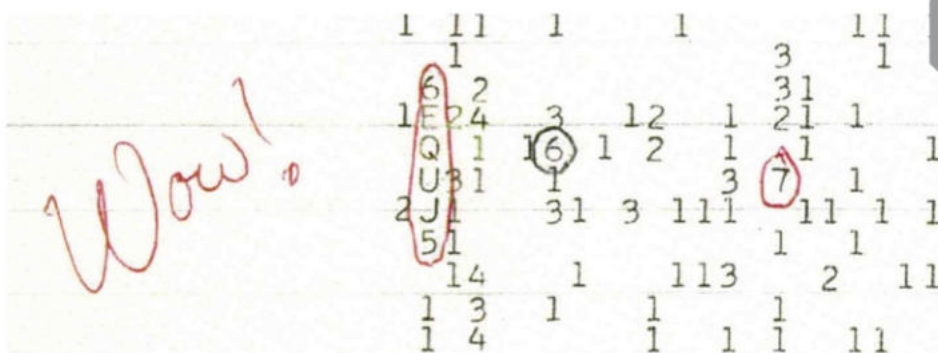


Things don't go too well for us Earthlings following a cultural misunderstanding in *Mars Attacks!*

movie *Mars Attacks!* You'd need an actual translation aid. We would need to be able to decipher the sounds and the syntax.

You would hope that aliens would be intelligent enough to help us by referring to things that we might also have a concept of, such as pulsars or the laws of physics. Of course it would take a long time for a reply to get there because even the nearest star is more than four light-years away.

Do I think there is intelligent life out there? I would put money on it tomorrow! So this project is definitely worth doing. Our curiosity demands it.



Could the 1963 'Wow! signal' be evidence of an extraterrestrial intelligence?

Green Men) because it was thought it might be an alien beacon. A pulsar is a rapidly rotating neutron star that emits a beam of electromagnetic radiation, appearing to blink on and off. Before the excitement over the first pulsar, there was an earlier false alarm in 1963 when a radio source labelled CTA-102 was declared by Soviet astronomers to be evidence of a supercivilisation. It was later identified as a quasar – the active nucleus of a distant galaxy.

While a genuine message from aliens

“If extraterrestrials wanted their message to be heard, they would surely make it look different to a natural signal”

has never been confirmed, mystery still surrounds a narrowband signal detected from the direction of the constellation Sagittarius by the Big Ear radio telescope, Ohio, in 1977. It is known as 'Wow! signal' because observer Jerry Ehman scribbled 'Wow!' on the computer printout. It was never detected again.

A radio signal might not be the only way that we could spot an alien race. Duncan Forgan, who researches planet formation and astrobiology at Edinburgh University, believes advanced aliens might have built giant artificial structures around other stars that optical telescopes could identify from the nature of the starlight. “The classic suggestion is that energy-hungry aliens might have built something called a Dyson sphere, which completely encircles a star and collects all its radiation,”

says Forgan. Some American teams are already looking for odd-looking stars that might appear very big and very cool.

Forgan's idea is to look for a variant that is not the full sphere but a spherical arc around the star, built to steer the star onto a different path. The inside of the arc is mirrored so that any radiation that comes from the star gets reflected back to it. “Stars are a balance of the radiation coming out and the gravity trying to pull it back in, so when you upset that balance by putting in this mirror then you create a force and the force pushes the star. It is a way of giving the star a nudge to push it out of the way of something dangerous, perhaps a cloud of molecular gas that might disrupt the star's magnetic field, which aliens rely on to protect themselves from radiation.”

Ian Crawford, Professor of Planetary Science and Astrobiology at Birkbeck, University of London, is pessimistic about the chances of detecting alien signals. “If the Galaxy was teeming with intelligent life, we would know about it. Where are they?” says Crawford summarising what's known as the Fermi Paradox. “It is very unlikely, almost inconceivable, that the Galaxy can be full of advanced civilisations and us not have noticed. So I actually think they are probably quite rare.”

Nevertheless, when the e-MERLIN network starts listening out for alien civilisations, it could be that a group of optimistic British scientists make what would surely be the biggest discovery in human history. ■

PAUL SUTHERLAND is a space and astronomy writer and columnist for *The Sun*

Find out more

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BBC Sky at Night Magazine

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Astronomy Now Magazine



Sky at Night
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WINNER

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Explorer-130M
Model illustrated

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BBC Sky at Night Magazine

Sir Patrick Moore Endorses Sky-Watcher Telescopes



"I have used a great number of telescopes; some are good, some mediocre and some bad. To me the Sky-Watcher range of instruments are very good indeed, & suited to amateurs of all kinds - and they are not priced out of the market! Excellent value. Use them and enjoy them."

Sir Patrick Moore CBE FRS (1923-2012)

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THE FUTURE OF GADGETS

TECHHUB

EDITED BY **DANIEL BENNETT**

➤ THIS MONTH

BILL THOMPSON

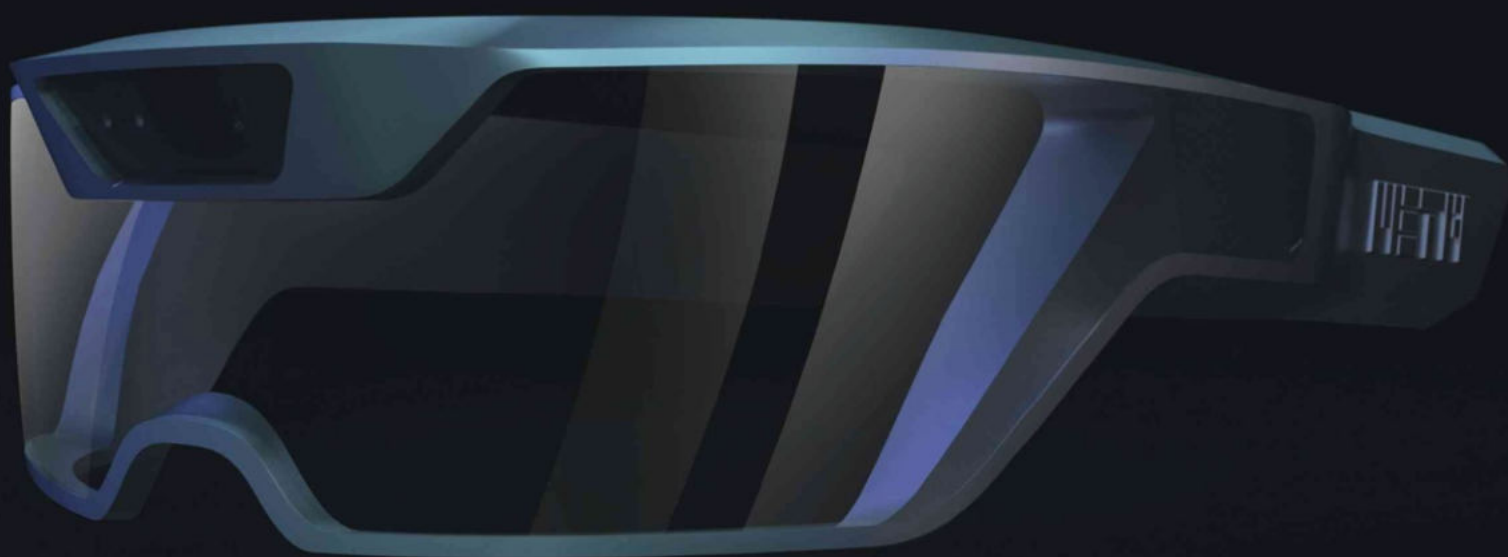
The age of wireless power
p101

JUST LANDED

Sky Now TV box
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ULTIMATE TEST

3D printers
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ON THE HORIZON

META

GLASSES THAT GO BEYOND
AUGMENTED REALITY

words: **SAM KLEIDSEN**

Spaceglasses.com,
\$667 (£428) plus P&P

GOOGLE GLASS may be grabbing all the headlines, but it's not the only form of wearable technology on the way. Take Meta, for instance, a futuristic-looking headset that will offer a 'mediated reality' experience when it launches this December.

Mediated reality is a little like augmented reality (or AR) in that it alters your perception of the physical world around you through the use of overlaid graphics. In the case of Meta,

you look through twin transparent LCD displays that can show text, 3D graphics and more. So far, so AR. Where mediated reality differs is that it can subtract objects from your field of view as well as add them. It's like an ad-blocker for the real world: mediated reality can remove things that you don't want to see.

To do this requires so-called 'featureless surface tracking', which scans the real-world environment using a camera and identifies – or at least attempts to identify –

A more streamlined version of the Meta glasses could look something like this when they go on sale in 2014



You don't even have to get your hands dirty to sculpt pottery with Meta glasses



→ everything within your field of view. Once the computer knows what you're looking at, it can enhance or diminish objects' visibility, and overlay graphics and text. AR uses markers for this – physical labels that the camera recognises – but with featureless surface tracking, everything in the world becomes a marker.

An example would be a blank sheet of paper. Meta's built-in 720p camera will recognise this for what it is, and the infrared 3D depth camera will track its changing position in the physical world. The headset can then 'print' text or graphics on the paper, which will behave as if it were real print: should you bend the paper or move it further from your face, the virtual print will move with it. It will even hide the text, or parts of it, should you turn the paper over or fold it.

Crucially, Meta is also able to recognise your hands and their position in 3D space, and will hide any graphics 'behind' them where necessary. And in a similar way to the Xbox 360's Kinect controller, it'll track hands and fingers to allow you to manipulate objects and graphics within its mediated reality world. So you and another Meta-wearer can play a game of chess on a

board that isn't really there, picking up and moving pieces with your hands. But there are bigger possibilities beyond just fun and games. Meta will also ship with software enabling wearers to use it for design, sculpting virtual 3D objects with hand-controlled mediated reality tools before sending them to a 3D printer for real-world creation. If that sounds reminiscent of Tony Stark in the *Iron Man* movies, that's unsurprising. Meta recruited Jayse Hanson, the man responsible for Iron Man's heads-up display in the films, to help design the device's user interface.

Priced at \$667 (around £430), Meta will be the first truly affordable mediated reality system available when it arrives in December. But the technology still has a fair way to go before it becomes as wearable as Google Glass: the sheer amount of sensors, cameras and processing power required means that the first generation of Meta is a pretty bulky device. A sleeker Streamlined Edition is due to launch in 2014.

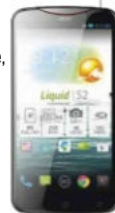
SAM KIELDSEN is a freelance technology journalist based in New York

TECHOMETER

WHAT'S HOT

4K RESOLUTION

Acer's next smartphone, the Liquid S2, will sport a camera that can record video in 4K resolution – that's four times more pixels than full-HD (1080p). Though the phone itself only sports a 1080p display, it's another sign that a shift in TV display to bigger, better resolutions is imminent. BSkyB recently carried out its first experimental live 4K broadcast in the UK, which was met with positive reviews in the UK press. So if you're considering buying a new TV, it might be worth holding out for 4K...



WHAT'S NOT

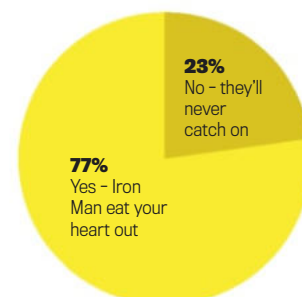
DIAL-UP INTERNET

BT switched off its dial-up service in September because only a 'tiny number' of customers still used it. The shutdown won't affect many people, though BT said about 1,000 dial-up users in remote areas who can't get broadband would have to change to another internet service provider. With more ISPs likely to follow BT's lead, it might not be long before that familiar, spine-tingling tone is a thing of the past.



READER POLL

Would you be seen wearing a pair of Meta glasses?



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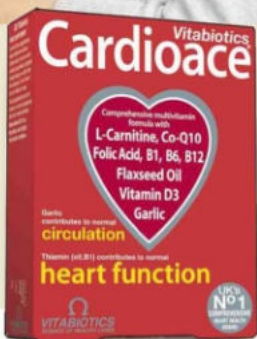
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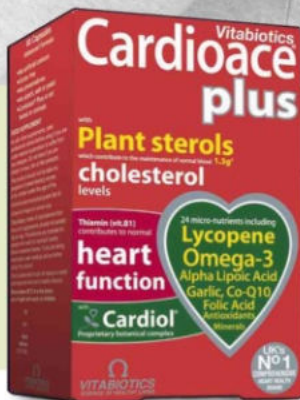
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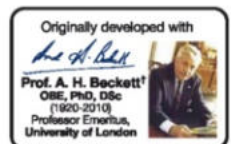
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- ♥ Maintain your body weight within the normal range for your height.



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THE NEXT BIG THING

POWER WITHOUT WIRES

The world is awash with electromagnetic radiation, and not just the sunlight that we can see with our eyes or feel on our skin. As you read this – if you're in the UK – radio waves from Radio 4, BBC One, Classic FM and the local taxi firm are all buzzing around your head, but you'd only notice if you built a tuning coil to listen in. These radio waves possess energy; real energy that can be used for practical purposes... if you can capture it and deploy it.

And now a group of engineers at the University of Washington in Seattle have figured out a way to do just that, turning the wash of EM waves in the atmosphere into a trickle of electricity that can power a sensor and a transmitter. This may not sound much, but it's one of those demonstrations of principle that's important because it turns what was an abstract idea into a concrete reality. And the widespread availability of electronic systems that don't need power sources could change the world.

The idea of getting power at a distance is not new, of course. You could argue that it's the basis of life on Earth, since photosynthesis relies on capturing the energy in photons of sunlight and turning it into chemical energy. It's a process that's analogous to using the energy of radio waves to power a circuit.

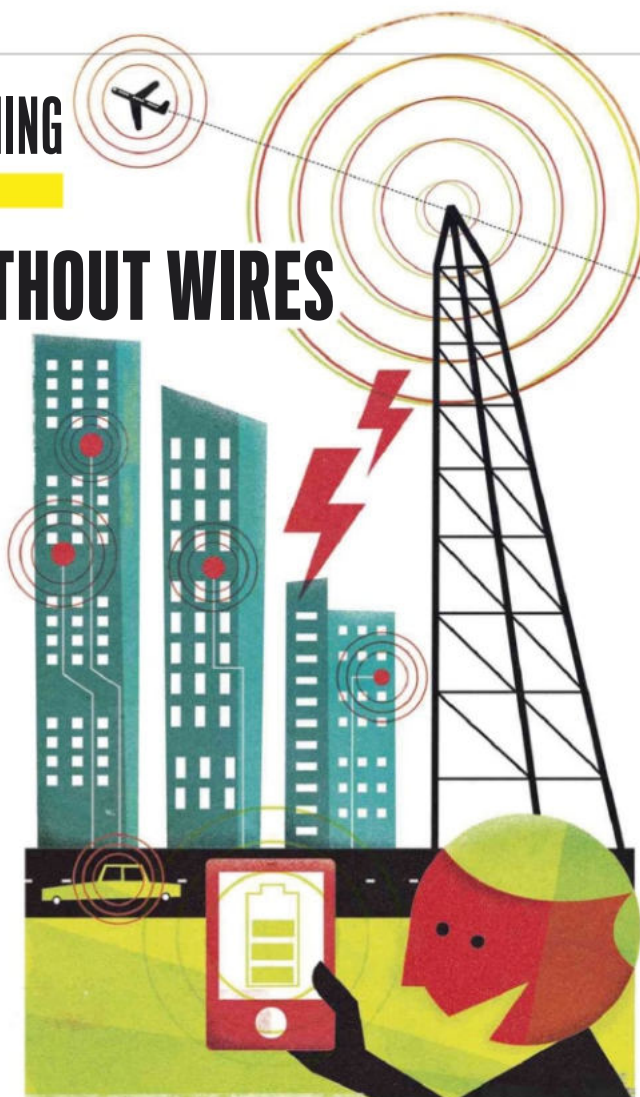
Harvesting power from radio waves won't just mean you'll never run out of battery on your phone

– the scale and potential impact are much more far-reaching than that. There are implications for the development of sensor-rich environments like smart cities. If we can build sensors into things and not worry about having to access them again, then architects could build them into floor tiles. Lifts could then tell if someone had pressed the 'call' button but then decided to take the stairs. We could have them surgically implanted without worrying about replacing batteries; scatter them along roadsides or train tracks to make travel smarter; put 'smart dust' in forests to detect fires before they get out of hand; or build them into aircraft frames to monitor stresses and strains.

Given that this is likely to happen, now is the time to discuss what a sensor-rich world looks like. CCTV crept up on us, Automatic Number Plate Recognition is poorly regulated, we've let our smartphones track us for years now and the NSA and GCHQ have taken advantage of the lack of regulation to monitor all this traffic. Perhaps we can put some sensible regulations in place for super-sensing buildings before we build them. It would make a nice change from the way we normally manage such things.



BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service



COMING SOON

3 MONTHS

SAMSUNG GALAXY GEAR

This smart watch lets you check texts and emails from your wrist and it can take grainy shots from its strap-mounted, 2-megapixel camera. So far, so Dick Tracy. However, it only works in conjunction with Samsung devices. Samsung.com



✦ **Xbox ONE** The next generation is here! Microsoft's new console goes on sale on 22 November, with Sony's PlayStation arriving a week later. Microsoft.com

✦ **Samsung Note 3** This phone/tablet hybrid is the first to make proper use of handwriting recognition. Jot a phone number on its screen and it will read the digits and store them for you. Samsung.com

6 MONTHS

VALVE STEAM BOX

Valve, the company that created the PC's most successful online games shop, wants to take over your living room. Its Linux-powered gaming box could transform the way we think about consoles. Valvesoftware.com



Google Glass

Everyone will be wearing their technology in 2014, and the Google Glass specs will be the must-have accessory. Google.com/glass

Haier Eye Control TV

Here's a telly you can control just by looking at it. It's fitted with eye-tracking tech to let you navigate menus. A prototype at present, it could be on sale next year. Haier.com

9 MONTHS

WHISTLE

Track Fido's activity and health with this new monitor. A batch of sensors log how much exercise, rest, sleep and play your pooch is getting and presents it as charts that you can use to monitor their fitness. Whistle.com



Intel gesture control

Intel is making its own motion-controlled hardware and software like the Kinect. It means new laptops will start coming with gesture control as standard. Intel.com

Alcatel One Touch Flip Cover

This smartphone has a colour screen and a case that snaps on to provide a second e-ink display. If you're just reading an e-book you can conserve battery life. Alcatel.com



JUST LANDED

SMART TV, SMART PRICE

Meet Sky's internet-connected set-top box, a Freeview challenger that costs less than £10. Joe Svetlik breaks out the popcorn

What is it?

SKY'S NOW TV is a set-top box that offers on-demand (and some live) channels for a one-off fee of £9.99. The box is small enough to fit in your hand, and there's no monthly fee, just like Freeview. You can also buy day passes to all six Sky Sports channels for £9.99, or unlimited Sky Movies access for £15 a month. And with the Sky Movies introductory offer you get a month free, then it's £8.99 for the first three months.

How does it work?

The Now TV box plugs into your telly via HDMI, and has a Wi-Fi connection. You'll then have to register your details online before you can get access to your on-demand and live channels. If you keep it in standby, you can get right to your channels instantly when you turn it on with no boot-up time.

How good is it?

Very good indeed. Set-up is a doddle. It found our Wi-Fi network with no trouble – though it doesn't play nice with Internet Sharing from a Mac, so you will need a wireless router. The menu screen lays out each service, whether it's on-demand or live TV, like apps on a smartphone.

There are four

initially on the main screen – Sky News, BBC iPlayer, BBC News and Demand Five – and then you can add more from the Roku Channel Store. There's plenty of unwatchable stuff in there (*Momversation*, *Horoscopes* by Kelli Fox), but some good ones too (CNET, Flixster and Vevo, as well as Facebook and Spotify) and Sky's Sports and Movie services. However, there's no Netflix, sadly.



It streams video in a quality up to 720p HD, and we had no glitches whatsoever. But there are a couple of minor irritations.

The volume varies quite a lot between channels, so Sky News is about the same loudness as the menu bleeps, but switch to iPlayer and you'll be deafened. The fast forward function also works differently from channel to channel. On iPlayer, press it once and you'll jump between 'chapters' or scenes of a show – four minutes in one case, seven in another – while on

Demand 5 it goes up incrementally, so one press goes 2x as fast, two presses 4x, and so on. Entering text is a chore with only arrows on the remote provided. A dedicated smart phone app with an on-screen keyboard would have been welcome.

Is it worth upgrading?

The Now TV box is an absolute steal. It might not seem as complete a package as Freeview or YouView – services like 4OD are notably

absent at the moment – but for £9.99 it brings a host of catch-up channels to your telly. Smart TVs have so far failed to take off in a big way, with clunky interfaces and no single operating system yet to emerge as industry standard. The Now TV box does everything Smart

TVs have been promising, at a fraction of the cost, and with no need to replace your existing set. ■

JOE SVETLIK is a tech journalist and news reporter for CNET

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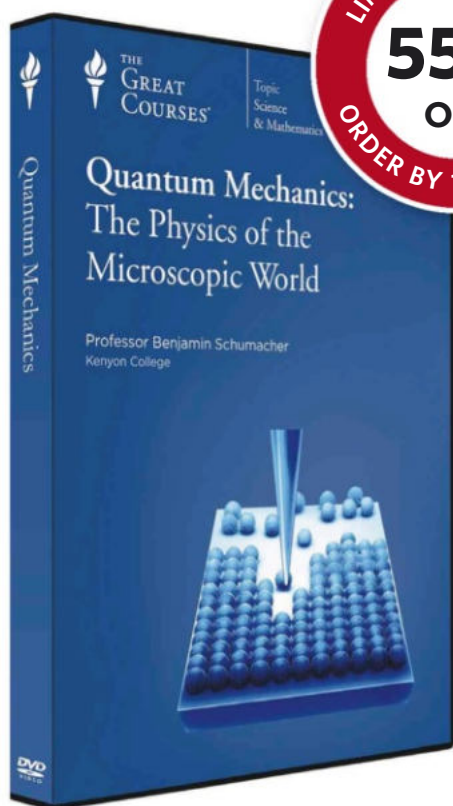
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APPLIANCES OF SCIENCE

1 ALIEN ACOUSTICS

While many gadgets are boring black boxes, these SoundSphere speakers look like they've been plucked from ET's living room. The alien design isn't just pretty though, it actually serves a purpose. Since your ears are particularly good at locating high-pitch sounds, the tweeters on these speakers are held at ear height so the sound feels like it's aimed directly at you.

Philips Fidelio SoundSphere, Philips.co.uk, £2,499

2 PLUGGED IN PICS

The best cameras are just that: cameras. They don't have Wi-Fi, apps or Bluetooth. But if you want some 'smart' features for your high-end snapper then there's the Weye-Feye add-on. It plugs into your camera via USB to create a Wi-Fi network. Use it to connect your smartphone or tablet and you can then control your camera remotely, upload pics wirelessly and edit them on the go.

Weye-Feye
Weye-feye.com, price TBC

3 TALK IN TONGUES

Fans of *The Hitchhiker's Guide To The Galaxy* will be familiar with the Babel Fish: a fictional creature that wriggles into your ear and translates languages for you. Well this device does the same, only without anything crawling into your head. The translation isn't word-perfect, but it works much better than taking the "let's just talk slower and louder until they understand" approach.

Sigmo
buysigmo.com, \$50 (£31.69) plus P&P

4 A GLOBAL PERSPECTIVE

Flat photos are so 2012; create spherical pictures instead with this Ricoh Theta camera that turns you into a walking Google Street View cam. The Theta uses a unique twin-lens system to capture 360° images of the world around you. It then transmits them via Wi-Fi to a smartphone or tablet so you can explore your image. They can be shared online as interactive pictures, or turned into 'photo orbs'.

Ricoh Theta
theta360.com, £329

5 SNAP-ON SNAPS

It may look like just a lens but this is actually an entire camera, even though it doesn't have a screen or viewfinder, or even a body. The idea is you clip it on to your smartphone, and the device uses near-field communication to connect to it. Once connected your phone takes over and shows you the view and all the controls. That way you're not stuck with the camera built-in to your smartphone.

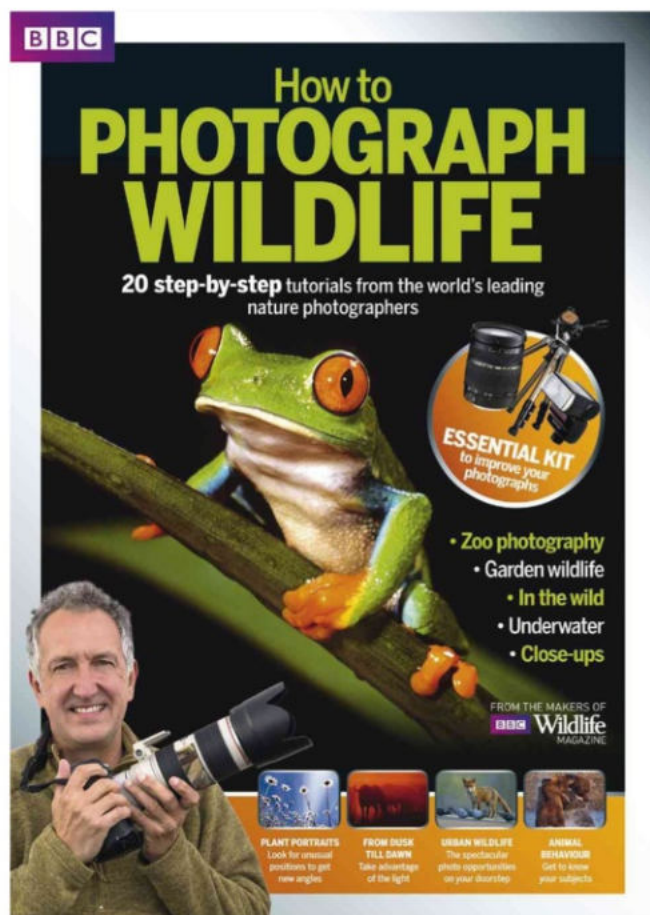
Sony QX10 & QX100
Sony.co.uk, £179 and £399 respectively

6 CONSOLE CROSSOVER

Although it's a PlayStation by name, this new Kit Kat-sized set-top box is very much about TV. When it lands in the UK, it'll take the On Demand streaming services available on the PS3 – like Lovefilm, Netflix and iPlayer – and put them on a cheaper, smaller device. It'll also play games from the PS Vita, Sony's handheld console, and stream games from a PS4 to a TV in another room.

PS Vita TV
uk.playstation.com, \$100 (UK price TBC)

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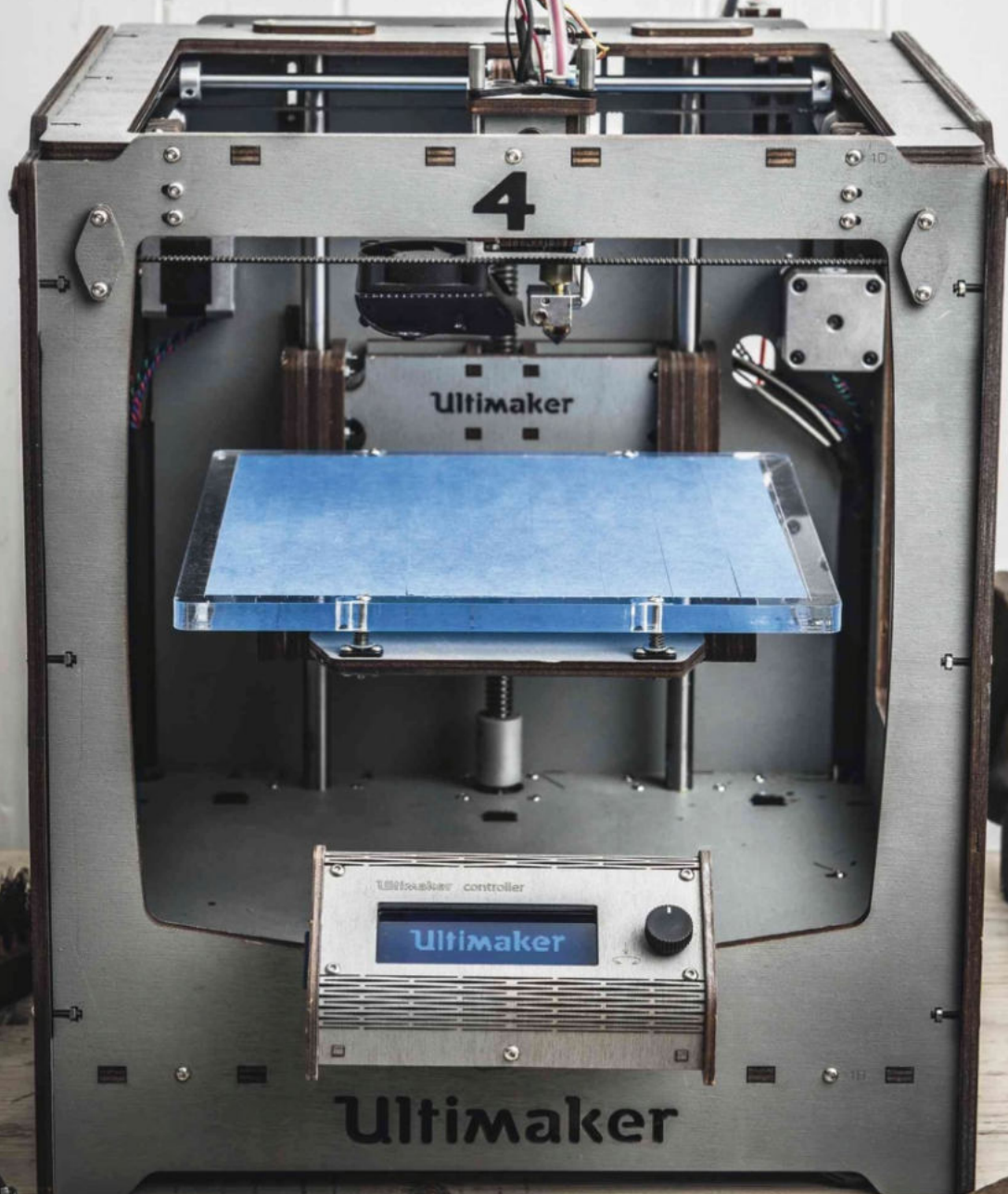
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 ULTIMATE TEST

A REVOLUTION IN THE MAKING



3D printing is transforming engineering,
but will it ever take off in the home?
Daniel Bennett fires up production

ULTIMAKER ORIGINAL

Ultimaker.com, €1,194 (£1,002)

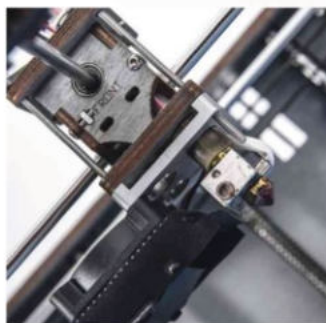
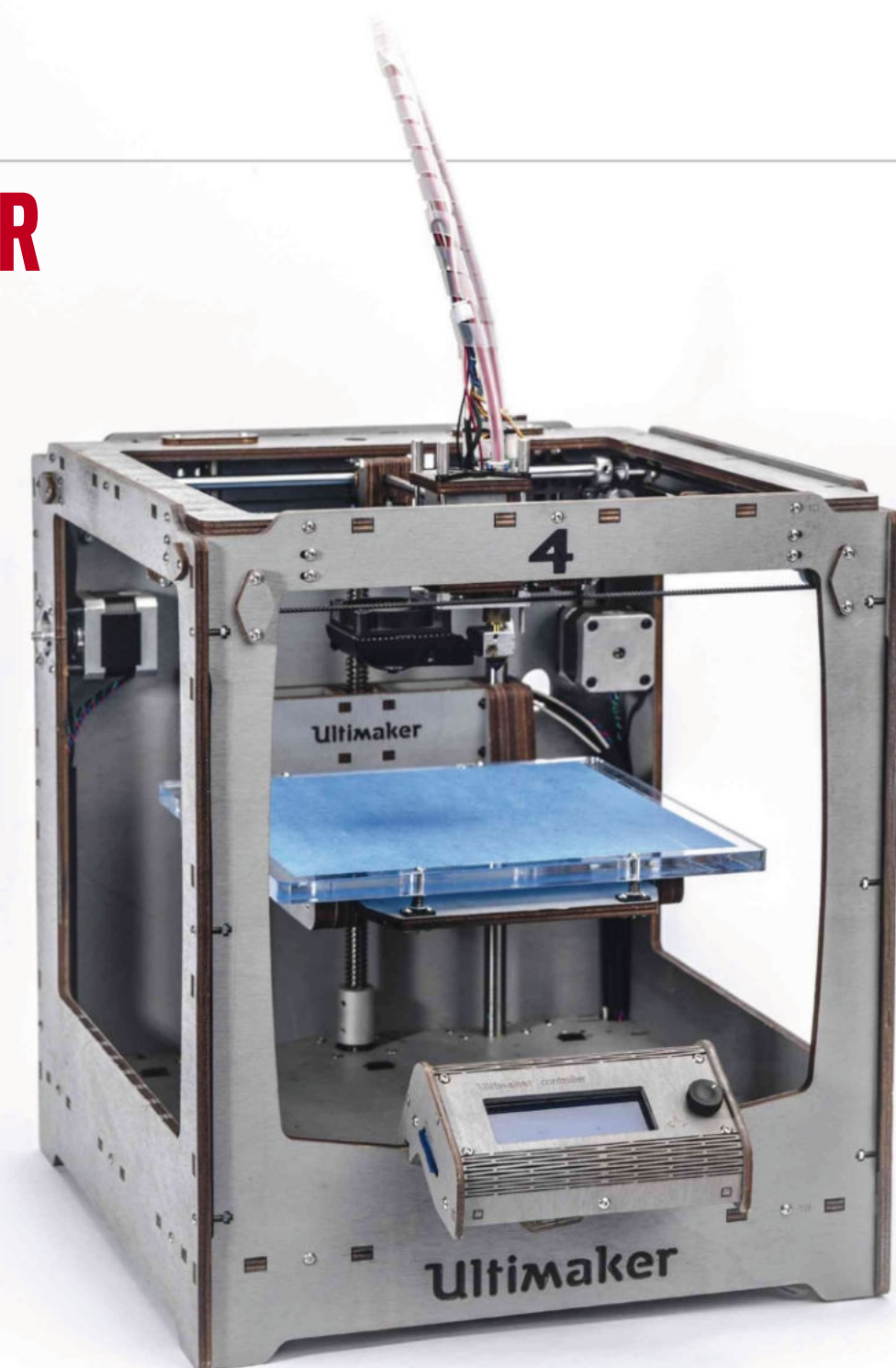
AT €1,194 (£1,002) THE Ultimaker is one of the cheaper 3D printers around. The fact that you have to build it yourself could make you think that this is a bargain basement device, but that would be missing the point. It comes as a self-assembly kit so that if you're so inclined you can make your own modifications and hacks to enhance the printer.

Ours came ready-made (this will cost extra), which is recommended if you've never built anything before. The Ultimaker is a relatively senior device compared to the Replicator 2, but it doesn't show its age. The software client, Cura, is friendly and easy to use, and set-up takes just a few clicks after plugging it into your computer. After downloading some models from Thingiverse – a library of free and paid-for 3D designs – it's quick enough to import the file to the printer, although the process is a little slower than the Replicator 2.

The Ultimaker might look a little rough around the edges, but its prints certainly aren't. It's cheaper so its specs unsurprisingly fall short of those of the Replicator 2, so our expectations weren't high. But what we printed (a toy rocket and an egg cup) surprised us. It lays down the PLA plastic much faster than any printer we'd seen before, and the resolution provided a supremely smooth finish.

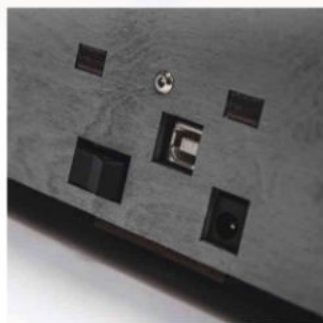
There's still a degree of trial and error where designs occasionally don't translate into the physical world as expected. This tends to happen when a design with unusual geometry requires the printer to build scaffolds. Though these are meant to snap away cleanly at the end, that's not always the case. What's more, as the melted plastic is extruded from the print nozzle it occasionally catches on the printed object, tugging it off its spot on the platform and ruining it.

■■■■■



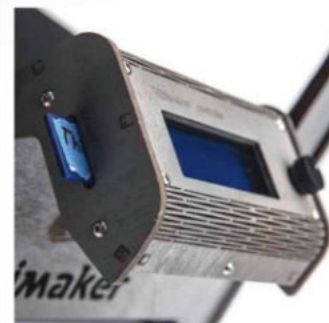
PRINT NOZZLE

Different nozzles and extrusion kits can be bought and fitted to the Ultimaker.



PORTS

PC or Mac devices connect to the Ultimaker via USB. There's no Wi-Fi connectivity yet.



CONTROL CONSOLE

Turn the knob to ramp-up the print speed, plus the SD card slot permits PC-free printing.

MAKERBOT REPLICATOR 2

Store.makerbot.com, £1,499



THE REPLICATOR 2 IS widely thought of as the standard-setter for 3D printing. Instead of the wooden, hackable frame favoured by its forebears, the Replicator has a black, steel finish. The idea, it seems, is to go for a more professional look that could move 3D printers out of the shed and into the home. Though the finish looks more polished, its bulky size and industrial styling means it's unlikely to fit in anywhere other than a construction site.

What it lacks in finesse on the outside, it more than makes up for in usability on the inside. The MakerWare software uses a drag-and-drop style interface that welcomes beginners. Its developers have clearly listened to user feedback and built a robust piece of software. For example, it gives you the option to print objects on any spot of the platform. This might sound like a minor option, but it means you can print several objects in one go – an obvious feature that's missing from a number of 3D printers. MakerWare also does the job of translating your design into a set of instructions for the printer better and more quickly than any other software we've tested.

The actual print out is rapid, and much quieter than other printers we've tested. Where you'd have to keep the Ultimaker in the shed just to spare yourself the noise, the Replicator 2 is quiet enough to keep in the office.

This 3D printer certainly feels like an evolution beyond the Ultimaker, and other early models. But it's still far from perfect. You'll still have a graveyard of failed prints from small errors and we did have to resort to the helpful support forum to sort out some minor niggles. It's not quite as 'plug in and print' as it would have you believe.



PRINT NOZZLE

The Replicator 2 extrudes plastic at 100 microns – the thickness of a sheet of paper.



PRINT SPOOL

The Replicator 2 uses PCA plastic filament, which costs around £30 per kilogram.

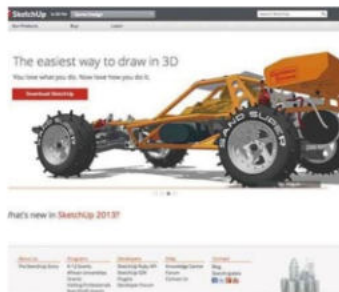
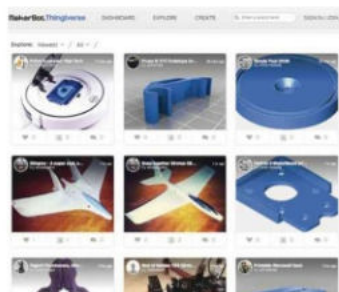


CONTROL CONSOLE

From here you can print straight from an SD card and make minor modifications.

HOW TO 3D PRINT WITHOUT A PRINTER

You don't need thousands of pounds to print your own 3D models. Here's how to do it for less...



THINGIVERSE



Complex robotic designs are now possible

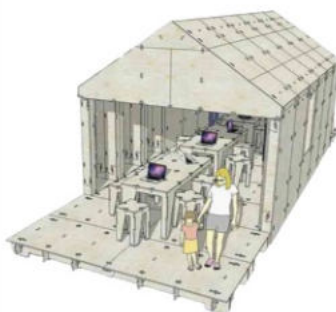
HOWEVER YOU INTEND to get your 3D models, Thingiverse should be your first stop. It's a digital library of thousands of free designs drawn up by amateurs and engineers alike. At first it might seem like it's mainly populated with figurines and smartphone cases, but closer inspection will uncover thousands of useful blueprints like wall plugs, robot bodies and spacecraft models.

Before you print, or send the design to a printing service, double check the dimensions of the object. We learned this the hard way when a vase we printed was actually the size of thimble. If you have a printer, changing the scale of your object, using software like MakerWare or Cura, is simple enough – but beware, the geometry might not always work at a larger scale. Finally, pay attention to the licence. While all the models are free, they can usually only be used in certain ways. For example, you probably won't be able to start a small company printing iPhone cases unless you've made one yourself.

Thingiverse.com

GOOGLE SKETCHUP

IF NOTHING TAKES your fancy on any of the 3D printing sites, then you can always create your own object – or even modify someone else's design. Google's SketchUp is the simplest way to draw in 3D, the only thing it requires is time. It won't have quite the full toolset of the more technical software aimed at architects and engineers, but it is surprisingly well equipped.



Designs for an entirely 3D printed house can be found on SketchUp

To get started there's a series of online tutorials and within 20 minutes I'd created my own basic robot figurine. When you're finished you simply save the project and import it as a .3ds or .obj file – these are the most common formats that printers work with. There's even an option within SketchUp to upload it straight to the printing service Sculpteo directly from the program. Finally, to fully embrace the spirit of open source design, you could upload it to Thingiverse and let others print your file or even improve it.

Sketchup.com

SCULPTEO

IF YOU'VE DOWNLOADED your design from a site like Thingiverse or created your own on Google SketchUp, then Sculpteo is the place to go to make your object a printed reality. It accepts almost every type of 3D file and even has a viewer that lets you make any final checks or changes live on the site.

Once you've readied your creation, the site takes you through diagnostics that check that your object will print as you expected. Then you can pick from 10 materials including ceramic and silver, as well as the more common plastics. If your design doesn't quite fit your budget you can even scale the print up or down so that it costs less to make.

While the website is good, the Sculpteo iOS app is even better. It has the same library of designs,



This beautiful representation of a frog is scarily real courtesy of Sculpteo

but through the app you're able to really customise them. For example you can combine a stock 3D model of a cup and a photo of your profile to create a mug with your mug on it.

Sculpteo.com

CUBIFY

CUBIFY SELLS ITS own home-friendly printers and community-created designs, which you can have printed and sent to you. From breathtaking light fittings to tiny washing machine components, there's something here for everyone, but when you visit Cubify make sure you check out their toys.

If you've ever dreamed of having an action man with your face on it then this is the next best thing. Upload a series of pictures of your face to the website and stick it on whatever figure you like: whether that's a zombie, a mummy or our personal favourite, a Federation officer from *Star Trek*. If you're looking for something more tasteful you could have surprisingly life-like figures made to top your wedding cake. There's even jewellery from established designers. But best of all, there's incredibly intricate 3D printed guitars.

Cubify.com



'Print me out Scotty'

3D PRINTING: NOW AND NEXT

Is it the right time to take the plunge?

SINCE WE TESTED our first 3D printer a year ago the technology has come a long way. Online libraries like Thingiverse and Cubify are brimming with toys, homeware and spare parts. The printers are better too. The resolution – and therefore the quality of print – has gotten sharper, the printers have become quieter and the whole process is faster and more user-friendly. And if you don't have a spare £1,000 to spend on a printer, there are reliable services that will print out models for you and deliver them to your doorstep.

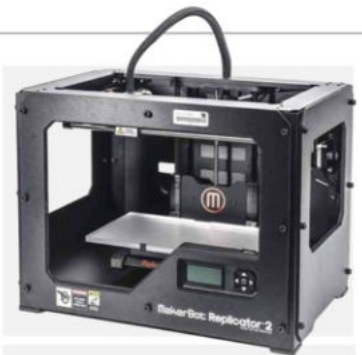
Despite all of this though, there's no killer application. Smartphones became ubiquitous over the space of five years because early adopters showed their friends the incredible things you could do with apps. The same can't be said for 3D printing. Sure, printing miniature figurines is fun, and creating spare parts can be useful. But there's no single use that will make the average person think 'I need one of those'.

PRINTING PLANE PARTS

The one place where 3D printing has taken off in a big way is manufacturing and engineering. Dyson, Airbus and NASA have all adopted the technology. You may have already flown on a plane with parts made in a 3D printer and one

VITAL STATS

Ultimaker versus
MakerBot – how the
specs compare



	ULTIMAKER	MAKERBOT REPLICATOR
SIZE:	358 x 338 x 389mm	490 x 320 x 380mm
BUILD VOLUME:	210 x 210 x 205mm	285 x 153 x 155mm
SPEED:	30-300mm/s	80-100mm/s
RESOLUTION:	Up to 20 microns	Up to 11 microns
COST:	£1,194 (£1,002)	£1,499

day you might see satellites or even Moon bases built using them. When this industrial-scale technology finally trickles down to shop shelves, 3D printers could take off in a huge way.

But what about now? The Ultimaker and the Replicator 2 are two very different breeds made at very different stages in the evolution of the technology. The Ultimaker is for the 'maker' who'll get a kick out of building a whole device from scratch and will relish the thought of

upgrading with parts they printed themselves. Meanwhile, the Replicator 2 is great if you want to print models with minimal fuss.

Both do the job well, but neither are perfect. They both make mistakes and occasionally act up. If you can spare the extra cash, then the Replicator 2 is the obvious choice, but if you have some spare time on your hands to build your own printer, then the Ultimaker will reward you with great prints for a lot less money.

3D PRINTERS OF THE FUTURE

Three printers that could kick-start a revolution



VADER SYSTEMS LIQUID METAL PRINTER

This is essentially an inkjet printer that squirts out liquid metal. It could drastically reduce the cost of car parts and the like. Mechanics and repairmen could design and print replacements. The printed components could even be better than the original since 3D printing can create objects more efficiently.

BOTOBJECTS

Whatever you decide to make with the Ultimaker or the Replicator 2, it'll have to be in one solid colour. This printer from BotObjects can switch between plastics seamlessly while your object is being

built, so you can finally create a single object out of several different colours, which will appeal to the community of people already using 3D printing to create homeware.



TNO FOOD PRINTER

While the idea of making a phone case might not get you rushing out to buy a 3D printer, printing out a meal might whet your appetite. Dutch company TNO has built a printer that's already making cakes, pasta and cookies with shapes that would have been impossible before.

Find out more

www.3Dprintshow.com

Visit this cutting-edge show when it hits London from 7-9 November

THE THEORY OF EVOLUTION

BY REBECCA STOTT

Charles Darwin put the pieces together, but he wasn't the only radical thinker when it came to evolution. Alfred Russel Wallace, who died 100 years ago, and Jean-Baptiste Lamarck were also pioneers

M

OST PEOPLE KNOW that the theory of evolution did not appear amongst us like a bolt from the blue with the publication of Charles Darwin's *The Origin Of Species* in 1859. But not many people are aware that the idea has been around in

various forms for at least two and a half thousand years.

Like us, the ancient Greeks failed to agree about the origins of life. Their cosmologies were profoundly different from our own. There were no heresy laws or inquisitions to fear or a dominant creation story to sidestep. Ancient Greek cosmologies were wildly variant: some believed that life had been shaped by gods; others that it had come into being through atoms colliding chaotically.

Empedocles – poet, healer, magician and controller of storms as well as a philosopher – produced a surreal foreshadowing of natural selection two and a half thousand years ago on the island that we now call Sicily. He proposed that life had started out

as random body parts – eyes, necks, arms, teeth – suspended in a primeval soup. Collisions had produced random combinations – men with the heads of cattle; animals with branches for limbs. Some of these combinations had proved viable, others not.

AN EVOLVING IDEA

A hundred years later, Aristotle declared Empedocles's theory absurd and unverifiable. Having studied under Plato in Athens, he then spent two intense years examining animals and plants on the island of Lesbos in the Aegean Sea, in an attempt to discover the laws of nature through close observation rather than by guesswork. Nature was not random and chaotic, he declared; it was eternal and deeply, perfectly patterned. Each organism fitted its place; the flesh of an individual plant or person might bloom and decay but species remained unchanging. He was no evolutionist but his stress on close observation above speculation makes him integral to this long history of evolution; he is

considered the father of biology.

No work rivalled that of Aristotle's detailed study of species for nearly a thousand years. In 9th-Century Baghdad, Al-Jahiz, an Arab philosopher working at the heart of the Abbasid Empire, having been inspired by Aristotle's recently translated volumes, set out to write his own compendium of zoological knowledge. In his seven-volume work *Living Beings*, he described the natural world in terms similar to the modern concept of ecosystems; he also saw everywhere what we would call the adaptation and diversification of species.

Some scholars claim that Al-Jahiz discovered natural selection a thousand years before Darwin; they see natural selection in his descriptions of systems of predation, co-dependency and survival, but Al-Jahiz was a devout Muslim, and his volumes, as an act of worship of Allah, described a natural world in which everything had been assigned its place in a divinely ordained system. It was not a mutable system.

In 15th-Century Milan, the painter, inventor and polymath





Finches that Darwin used as evidence for a theory of evolution rest on his masterwork: *The Origin Of Species*

> IN A NUTSHELL

Many theories have a long history, but few are as rich as evolution. Even the ancient Greeks touched on evolution before the great thinkers of the 18th and 19th centuries bore it out with a remarkable idea: natural selection.

➔ Leonardo da Vinci read Arabic and Greek philosophy and natural sciences. One of the natural philosophical questions that vexed him was how fossilised oyster beds had got themselves into the tops of mountains. But though he asked questions that would lead 19th-Century geologists to evolutionary conclusions, he was not much interested in questions of species. What he saw in fossils was evidence to support his Neo-Platonist beliefs: that the human body was a microcosm of the Earth, subject to similar laws. Leonardo was taking significant risks in asking such heretical questions about the nature of the Earth. He may have developed his mirror-writing to protect his notebooks from the prying eyes of inquisitors and priests.

Through the 18th Century the publication of new works on insects

and the development of microscopes inspired a generation of young men to study the reproductive behaviour of microscopic organisms. Occasionally they discovered disturbing and inexplicable things.

In the summer of 1740 Abraham Trembley, a young Swiss tutor educating the sons of the Count of Bentinck in The Hague, sent his young charges to collect pond water for the microscope. He proposed that they do some experiments on the creatures (he called them polyps; we know them as *Hydra*) they found in the estate's ornamental ponds. Trembley was astonished to discover that when he cut the organisms in half, they regenerated themselves. Such a phenomenon appeared to violate the prevailing understanding of natural laws: plants re-grow after cutting; animals don't. But the polyp did.

The polyp quickly became the talk of European salons, used by materialists and atheists alike to demonstrate that life was to be found within material flesh not outside it. Debates about the nature and origins of life had taken a strange new turn.

Altogether stranger evolutionary ideas began to emerge in Cairo around the turn of the 18th Century. The French consul here, Benoît de Maillet, had brought the philosophical questions of the French salon culture – debates about the age, origin and nature of life on Earth – to Egypt. The ancient remains he saw in the desert suggested that the Earth was much older than the French Catholic priests claimed. The Arab traders and religious leaders Maillet met proposed quite different cosmologies and ways of understanding the Earth's formation. He became convinced that

THE KEY DISCOVERY

Natural selection was the most important milestone in the long history of evolution, because it provided a mechanism to explain how the theory worked

THE CRUCIAL BREAKTHROUGH in the history of evolution should be regarded as a 'convergent' one. In 1858 while suffering from malaria fever in the Malay Archipelago, Alfred Russel Wallace discovered natural selection under his own steam: the reason why some species survive and others die out is that the fittest survive. Charles Darwin had already found this during his travels around South America on the *Beagle* – reading Malthus's book on population in 1838 provided the final piece of the jigsaw. He understood that evolution worked through a 'struggle for existence': favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species.

From this point on, Darwin committed himself to gathering evidence. This is one of the reasons why it took him so long to publish his species book. When Wallace sent him his still-unpublished essay on natural selection in 1858, Darwin finished his book in a matter of weeks and rushed it to press. The Linnaean Society declared Darwin the first to have discovered natural selection because he was able to submit evidence that he had defined the idea – though not published it – many years before Wallace.



An illustration from *The Malay Archipelago* by Alfred Russel Wallace (1874); the work described Wallace's ideas that led up to the idea of natural selection and a theory of evolution

Egypt – indeed the Earth's crust as a whole – had been formed by waters gradually receding from a universal ocean, and that all humans had evolved from 'seapeople'. Some of these intermediate forms, he proposed, still survived. He spent his fortune travelling around Europe collecting evidence of seamen sightings. Due to the heretical nature of his claims he was unable to publish his strange book, *Telliamed* (his own name spelt backwards) during his lifetime. It only began to circulate, clandestinely, 50 years later.

FREEDOM OF THOUGHT

By the 18th Century, Paris and Amsterdam had become hubs of intellectual subversion, part of a network that stretched across Europe; anti-clerical books, pornography, atheism and books on natural science or free thought travelled down the same routes. In Paris, the newly formed secret police, led by Joseph D'Hémery, kept unorthodox philosophers under surveillance.

The playwright, philosopher and encyclopaedist Denis Diderot was one of the most dangerous subversives according to the police files. Diderot had read papers about Trembley's polyps, Maillet's *Telliamed*, and most new papers and books on the natural sciences. In his plays, philosophical speculations and encyclopaedias, he proposed that the Earth was inconceivably old, that species had mutated through time, and that man would one day become extinct.

Like Maillet and his contemporary the Comte de Buffon – who slipped evolutionary ideas into his great volumes on the history of the animals – Diderot, fearful of prison, published his most radical ideas posthumously.

A few decades later the French Revolution produced the conditions in which evolutionary ideas flourished most rapidly. There were no priests to police philosophical questions or threaten inquisition. Napoleon had brought the largest collection of natural history specimens in history into the Museum of Natural History in Paris, specimens looted from European palaces. He appointed 12 professors to the Jardin des Plantes to work on a number of natural philosophical problems, alongside students from all over Europe. It was not long before the most

CAST OF CHARACTERS

Throughout the 18th and 19th centuries, great thinkers forged the idea of evolution



Erasmus Darwin (1731-1802) was a Derbyshire inventor, poet and doctor who proposed in *Zoonomia* (1794-6) that all living beings had evolved from simple aquatic organisms. He was the grandfather of Charles Darwin.

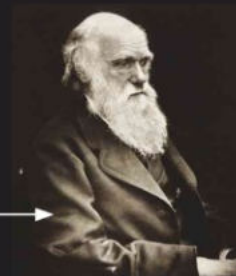


Jean-Baptiste Lamarck (1744-1829).

A French professor of invertebrates. He proposed that all species had evolved through great lengths of time from simple to complex organisms through the inheritance of acquired characteristics.

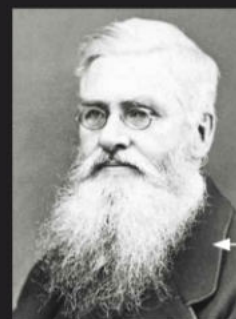


Robert Chambers (1802-1871) was a Scottish publisher and encyclopaedist, who published *Vestiges Of The Natural History Of Creation* in 1844. It was an attempt to marry together all the recent discoveries in the sciences to propose that the Earth had evolved from a nebulous fire mist and that all the species on it had transmuted from simple organisms.



Charles Darwin (1809-1882). The

British naturalist published *On The Origin of Species By Natural Selection* in 1859. It proposed that natural selection – the survival of the fittest – was the mechanism by which evolution worked.



Alfred Russel Wallace (1823-1913) was a British collector and naturalist who in 1858 co-discovered natural selection while out in the Malay Archipelago.

TIMELINE

The foundations of thought upon which the theory of evolution rests took many people over a century to develop

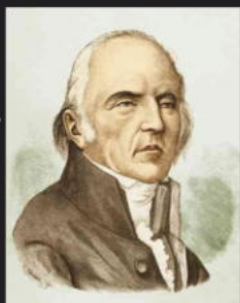
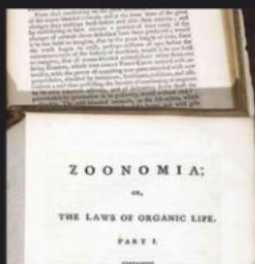


The *Telliamed*, written by Benoit de Maillet (left) between 1722 and 1732, is published posthumously. Maillet proposes that humans have **evolved from aquatic organisms** and that intermediate half-animal half-fish creatures survive.

1748

1794-6

Erasmus Darwin publishes *Zoonomia*, or the *Laws Of Organic Life*, a two-volume medical treatise containing a chapter called 'Generation' in which he proposes that **all living beings have evolved from aquatic filaments**.



A Professor of Invertebrates in Paris, Jean-Baptiste Lamarck (left), gives a lecture in which he proposes that all species have **evolved through great lengths of time** and that they have evolved through the need to **adapt to the environment**.

1802

1858

Whilst in a delirious malaria fever in the Malay Archipelago, Alfred Russel Wallace (right) **discovers natural selection**.



Charles Darwin publishes *On The Origin Of Species By Natural Selection* in which he provides detailed **evidence for natural selection** as well as a carefully extended argument for this being the mechanism by which evolution works.

1859

carefully worked out theory of evolution thus far emerged.

From 1801 until his death in 1829, the Parisian Professor of Invertebrates and Worms, Jean-Baptiste Lamarck, proposed that nature had worked to transform species over unimaginable tracts of time from single-celled to complex organisms. The environment caused animals to adopt new habits to survive, he claimed; in so doing they produced new structures – teeth, limbs for running, tongues or long necks. His ideas were both mocked and refuted by his more powerful and influential colleague in the Jardin, the great comparative anatomist Georges Cuvier.

GREAT MINDS THINK ALIKE

Lamarck and Erasmus Darwin reached similar conclusions about the evolution of species at about the same point without knowing each other and by different routes. Darwin, who was a poet and inventor as well as a doctor, proposed that all organisms had once been aquatic filaments in a universal ocean. Such ideas were dangerous; in the wake of the revolution Darwin and his philosopher friends were also under surveillance, even in rural Derbyshire. Like Diderot, Darwin slipped his most controversial ideas into footnotes or into poetry and published his most radical theories posthumously.

In the first decades of the 19th-Century, Lamarck's influence fanned out from Paris across Europe; the thousands of young and idealistic students who studied with him took Lamarckian ideas like seeds back across the world. Many used them to underpin reformist agendas.

In 1825 when a 16-year-old Charles Darwin arrived in Edinburgh to study at the medical school, he was befriended by a physician who had studied with Lamarck. Robert Grant, Darwin remembered, explained Lamarck's ideas to him and reminded him of how remarkable his grandfather Erasmus's ideas had been. When he set off on the Beagle reading Lyell's *Principles Of Geology* he opened a notebook that he titled the 'Transmutation Notebook'. His hunt for proof of the mutation of species had begun.

The branching and converging patterns in this history continue. In Scotland in the late 1830s, as Darwin returned from the Beagle voyage with an embryonic theory of natural selection, a young publisher called

NEED TO KNOW

Important terms surrounding the theory of evolution

1 LAMARCKISM OR LAMARCKIAN EVOLUTION

Also known as soft inheritance, it's the idea that an organism can pass on characteristics acquired during its lifetime to its offspring. It is named after the French biologist Jean-Baptiste Lamarck.

2 NATURAL SELECTION

The key mechanism of evolution. This is the process by which biological traits become more or less common in a population as a result of the effects of inherited traits on the reproductive success of organisms. Sometimes called 'the survival of the fittest', it was co-discovered by Wallace and Darwin.

3 TRANSMUTATION

An early term employed to describe evolution. It was used alongside others such as the development theory or transformism. British scientists like Lyell sometimes used it to discredit the theory by implying a connection with alchemy or magic - transmutation being a key term in alchemical theory.

Robert Chambers found himself converted to transmutationism by reading accounts of Lamarck and Erasmus Darwin's ideas. His sensational book *Vestiges Of The Natural History Of Creation* published anonymously in 1844, was elegantly written and cheap to buy. It fused together new discoveries in zoology, botany, and geology to give an account of the history of the Earth and of the evolution of species. *Vestiges* made a number of mistakes in its accounts of new scientific discoveries, and shocked the establishment to its core. But by bringing evolution into the drawing rooms of the public and into speculative conversation, it paved the way for new, more evidence-based theories.

A remarkable young land surveyor called Alfred Russel Wallace read *Vestiges* in the Leicester public library in the late 1840s. A few weeks later he read Malthus's *Essay On The Principle Of Population*. *Vestiges*, Wallace told friends, was the book he'd been



Napoleon's specimen collection at the Museum of Natural History in Paris sparked a surge of interest in theories of how life on Earth was able to become so diverse

waiting for all his life: a coherent account of the history of the Earth. But Wallace was also frustrated at the lack of proof *Vestiges* provided. When he set off with his friend Edward Bates to collect natural history specimens in Brazil, he determined to bring back the evidence. Ten years later an exhausted Wallace, sweating and hallucinating his way through a malaria attack on a remote island in the Malay Archipelago, suddenly saw how evolution might work: 'It occurred to me to ask the question, Why do some die and some live?' he wrote. 'And the answer was clear, that on the whole the best fitted survive...'

Back in Britain, Darwin already knew this. He'd begun to put his theory of natural selection together in his notebooks of the 1830s and developed it into an unpublished essay in 1844; that essay was still locked away in a drawer. Busy working on the Beagle collection, distracted by an eight-year project on barnacles, and alarmed at the vitriol *Vestiges* had drawn from the establishment, he'd determined to bide his time. When Wallace wrote to him in 1858 and sent him his essay on natural selection, Darwin was

devastated. He brought in his friends to adjudicate: What was the gentlemanly way to behave? The Linnaean Society gathered; they made their judgement: Darwin had drafted the idea 10 years before Wallace. Wallace gracefully conceded. He'd never claimed priority, he said. He was honoured to be associated with the idea and with the great Charles Darwin.

Historians still debate the ethics of that decision, but as a consequence Wallace returned to his beloved fieldwork and Darwin began the long and difficult campaign to defend the theory. Darwin, with his collection of detailed evidence, his persuasive rhetorical skills, reputation, status and wide circle of supporters, was without doubt the better man for that task. ■

Rebecca Stott is the author of *Darwin's Ghosts: In Search of the First Evolutionists*

Find out more

Listen to an episode of BBC Radio 4's *In Our Time* on Alfred Russel Wallace <http://bbc.in/13XqeXP>

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TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

-  VISIT
-  WATCH
-  LISTEN
-  TOUCH
-  PLAY
-  READ



Light And Dark

Physicist Jim Al-Khalili presents a two-hour guide to light, the Universe and everything

➔ YOU CAN'T KEEP Jim Al-Khalili off a good fairground ride. In his previous show, *Everything And Nothing*, Jim was seen sliding down a helter-skelter just to illustrate the nature of gravity. And now, in this new two-part series, he unravels the very nature of the Universe while riding on a waltzer. Putting aside his obvious affinity for amusement parks, though, the physics professor has a real knack of making complex ideas sound like child's play. So he's the perfect person to guide us through "the story of everything we know, and everything don't know about our Universe".

As the first episode explains, our understanding of light has been the key that's unlocked many of the mysteries of the cosmos. And there are few better places to begin a story about light than with Euclid, a Greek mathematician who in 300BC recognised that light travelled in straight lines. From there, Jim guides us through thousands of years of ideas, from Galileo's telescope right up to the MIT team that caught a pulse of light moving through a bottle on film.

On paper, *Light And Dark* sounds denser than the black holes Jim describes, but his delivery makes

light work of the many experiments and equations. Indeed, it's only when we reach the darker elements of the cosmos that things get a little murky. Then again, even the scientists sat beneath the Gran Sasso mountains hunting for dark matter aren't sure what it's made of. And it's here, where the DarkSide sensor is about to start looking for evidence of the mystery stuff, that the show is at its strongest. When Jim talks to fellow physicists about cutting-edge science, he looks almost as excited as when he's visiting an amusement park.

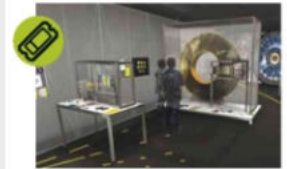
While *Light And Dark* might not have the grandeur, or the budget, of a series like *Wonders Of The Solar System*, it tells the tale of how we came to understand our Universe just as elegantly. If you've ever looked up at the sky and wondered how we know what we know about the cosmos, *Light And Dark* is unmissable TV.

DANIEL BENNETT



Light And Dark airs on BBC Four in November - see radiotimes.com for details

DON'T MISS!



Collider

Ever fancied a wander around the inside of the Large Hadron Collider? This Science Museum exhibition is the next best thing. **p120**



Beyond: Two Souls

The latest movie-style game from David 'Hard Rain' Cage ventures boldly into the world of the supernatural. **p125**



Scarcity

This new book examines how a lack of resources or opportunities plays a key role in shaping our society and behaviour. **p126**



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

24 OCTOBER - 3 NOVEMBER

Manchester Science Festival

Various venues, 24 October-3 November,
www.manchestersciencefestival.com



THE CHEETAH IS not the fastest animal: peregrine falcons can dive-bomb at speeds of up to 320km/h (200mph). Find out incredible facts like these at talks on subjects as diverse as 'What it's like to be a bird' and 'The cosmic tourist'. Plus you can meet real scientists, debate important scientific issues and watch comedy shows.

31 OCTOBER

Animating Architecture

Darwin Lecture Theatre, University College London, Gower Street, London, 1.15pm-1.55pm, free, <http://bit.ly/15JRael>



AT THIS TALK, don't expect to be sold a medieval vision of spinning towers like in the title sequence of *Game Of Thrones*. Ollie Palmer, from UCL's Bartlett School of Architecture, reveals a more technophilic urban world where the built environment is increasingly inhabited by AI systems, contextually aware gadgets, robotic agents and sensory spaces.

31 OCTOBER

Lates At Life: Halloween

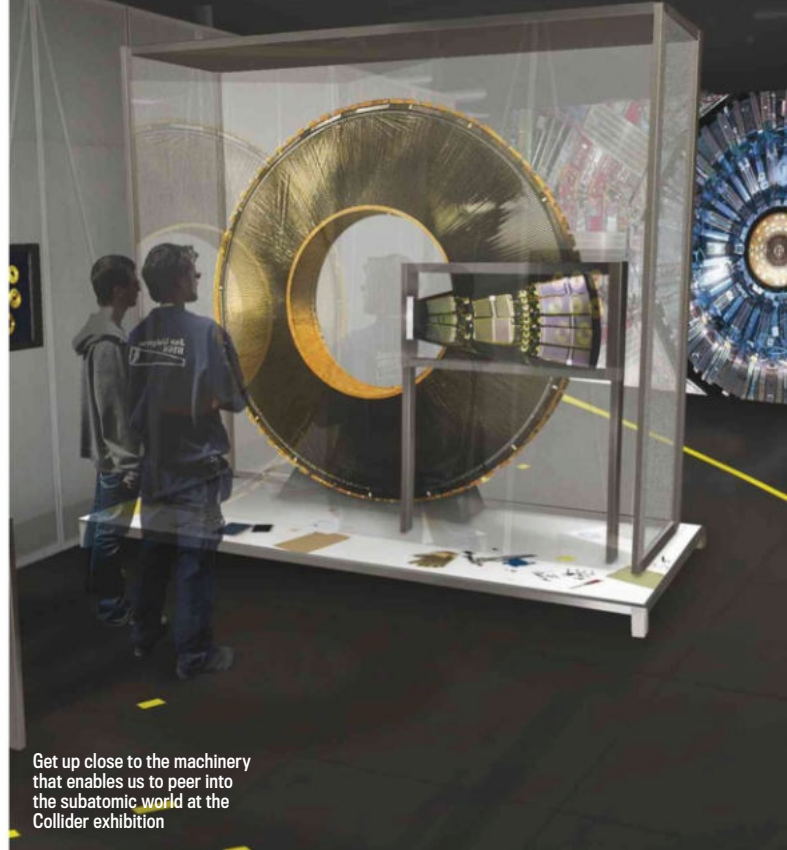
Life Science Centre, Newcastle, 8pm-midnight, £4, to book call 0191 243 8223, www.life.org.uk/whats-on/events/lates-at-life-halloween-2013



THIS THREATENS TO be a scarily good night out. No kids, no queues – what's not to love at this adults-only evening? Explore the Life Science Centre as you sip on bone-chillingly cool cocktails, listen to devilishly good tunes and ride the brand new Frankenstein 4D Motion Ride. Plus there's a prize for the best fancy dress – the more ghoulish the better!

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

EDITOR'S CHOICE



Get up close to the machinery that enables us to peer into the subatomic world at the Collider exhibition

13 NOVEMBER-30 APRIL

Collider

Science Museum, London, 13 November-30 April,
www.sciencemuseum.org.uk/collider



INSIDE THE 27KM-LONG tunnel of the Large Hadron Collider, sub-atomic particles smash together at 99.9999999 per cent the speed of light – equivalent to the energy of two cars crashing at 1,600km/h (1,000mph). These collisions occur around 800 times a second, and are captured by four vast detectors that lie 100m beneath the French-Swiss border at CERN. So as not to miss an impact, the Atlas detector snaps images 40 million times per second. Some pretty impressive statistics, we're sure you'll agree.

In this exhibition, designers and theatrical experts have created an experience that transports visitors into the heart of this great scientific and engineering endeavour. Get up-close with examples of CERN engineering, from the bottle of hydrogen gas that feeds the great machine to its vast dipole magnets. You can also discover a treasure trove of related memorabilia, such as JJ Thomson's Victorian apparatus that led to the discovery of the electron, and the accelerator that Cockcroft and Walton used to first split the atom in 1932.

5 NOVEMBER

Science And Society 2013

Leggatt Theatre, University of Liverpool, 5.30pm-6.30pm,
www.liv.ac.uk/events



AFTER EXTENSIVE TESTING, scientists at CERN are 99 per cent sure that the particle discovered last year was the elusive 'God particle'. But many still ask why the UK should invest in fundamental discoveries such as the Higgs particle. At this lecture Prof John Womersley, CEO of the Science and Technology Facilities Council, has the answer.

9 NOVEMBER

Chain Reaction

Cambridge Science Centre, 9 November,
www.cambridgesciencecentre.org/whats-on/exhibitions

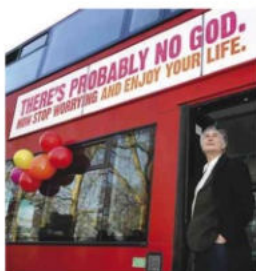


Scrapheap Challenge meets playground inventions. Come along and see whether all the different contraptions created by school kids will successfully stitch together on the day to become one big long chain of reactions. Plus, The Naked Scientists will be on hand with their explosive show entitled Crisp Packet Fireworks. The mind boggles...

10 NOVEMBER

Science And The Rise Of Atheism

Conway Hall, Holborn, London, 11am-12.30pm, £5,
<http://conwayhall.org.uk>



IN THIS TALK, philosopher and author Russell Blackford examines myths and misconceptions about atheism and atheists. He discusses whether there's a link between the rise of modern science and the rise of modern atheist thought, suggesting that science has helped erode religious belief.

16 NOVEMBER

Consensus?

ExCel, London, £28-£148, www.entangled-bank.co.uk



JOIN COMEDIAN BILL Bailey, ex-*Material World* presenter Quentin Cooper and the three Richards - Dawkins, Fortey and Wiseman - for a day of science and debate. After individual talks, there'll be a group discussion, which could go anywhere. If Bill Bailey's involved, expect to be led down a rabbit warren and back through a wormhole...

SPEAKER OF THE MONTH

1 NOVEMBER

Dr Simon Werrett

Royal Society, London, 1pm-2pm, free,
<http://royalsociety.org>



Who is he?

He's a lecturer in History and Philosophy of Science at UCL, currently researching the history of recycling and sustainability. By exploring chemical labs, flea markets and dust heaps, he's looking at the changing relationship between recycling, science and medicine through the centuries. But he's also a bit of a fireworks expert, having written books on the subject.

What's he talking about?

In a talk called 'Incendiary Science' he'll reveal how fireworks were used in early experimental science to attempt to answer questions such as how does combustion work and why does gunpowder explode? Grab this chance to soak up pub-quiz facts to impress your mates when you're all shivering round a bonfire on the 5th.

UNTIL 8 NOVEMBER

Fossils: The Evolution Of An Idea

Royal Society, London, free, <http://royalsociety.org>



Fossils: they're not what they were...



ICHTHYOSAUR OR 'FISH lizard' is a fitting name for the giant marine reptile that ruled the prehistoric seas. Fossil hunter Mary Anning discovered the first ichthyosaur skeleton to be correctly identified while digging on Devon's Jurassic coast when she was just 12 years old. This is on display in this exhibition of fossils from the Sedgwick Museum, alongside treasures from the Royal Society Library. The illustrated books reveal how ideas about fossils evolved through the centuries, helping to answer questions about the history of the Earth.



WATCH

TV, DVD, BLU-RAY & ONLINE
WITH TIMANDRA HARKNESS

FROM 19 SEPTEMBER

Through The Wormhole

Discovery Science, starts 19 October, 9pm



A RETURN OF the series that adds even more gravitas to questions like 'How do aliens think?' and 'Is reality real?' by putting them into the mouth of Morgan Freeman. This, the third season, continues the winning formula of experts, new research and high-tech visual effects – and of course the Hollywood touch that Freeman brings.

FROM 21 OCTOBER

Lost Civilisation Week

H2, starts 21 October, 8pm



HOW CAN CIVILISED human life be reduced so swiftly from calm and plenty to devastation and mayhem? But enough about half term: H2 has a week of programmes about historic societies that vanished. From Ancient Egypt to Machu Picchu (left), can archaeology and science explain the secrets of their catastrophic failures?

FROM 24 OCTOBER

Shackleton: Death Or Glory

Discovery, starts 24 October, 9pm



SIR ERNEST SHACKLETON is still admired for leading five men safely across 1,300km of the roughest ocean on Earth, in winter, in an open wooden boat. That was in 1901. Now, explorer Tim Jarvis attempts to recreate the expedition (left) with the same equipment and clothing. They plan to use scientific analysis to discover how Shackleton did it.

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze

EDITOR'S CHOICE



Dr Shini Somara and Jem Stansfield are on a mission to liberate Britain's shed-based geniuses

NOVEMBER

Make Me A Millionaire Inventor

Sky1, November

IMAGINE HAVING A brilliant invention, filing a patent but then being too shy to go on *Dragons' Den*, so it never gets further than your shed. Then, perhaps years later, a friendly TV presenter who's also an engineer turns up on your doorstep, saying they found your patent and they want to help you make it a reality.

That's what happens to 16 lucky inventors in this new series. Jem Stansfield (of *Bang Goes The Theory*) and Dr Shini Somara find languishing patents that inspire them, track down the inventors and work with them on building prototypes and pitching to business partners.

From baby bottles to folding boats, the range of ingenious ideas is delightful. Jem is particularly impressed by a

sunlounger that rotates as the Earth turns to keep you baking. And Shini finds a car numberplate that can flash 'STOLEN' to passersby without the thief knowing.

Jem's an inventor himself, though his wall-climbing suction gloves, pedal-powered aeroplane and jet-powered sheep have yet to reach the market. So he has every sympathy with the difficulties of turning a groovy idea into a product people can use.

But as always, it's the human stories that are the most gripping element: the shy pilot who needs to overcome his nerves to sell the teddybear that hugs you back, or the pig-farming couple who claim they have beaten travel sickness with their unique sunglasses.

NOVEMBER

The Maudsley

Channel 4, November TBC



ANXIETY, DEPRESSION AND psychosis can be just as debilitating as physical illness. Now, the team that made *24 Hours In A&E* go inside Britain's best-known psychiatric Trust to meet doctors, staff and patients. Hear first-hand from those who have to make life-saving decisions, and those who live every day in a battle with their own psyche.

NOVEMBER

Living On The Edge

Channel 5, November TBC

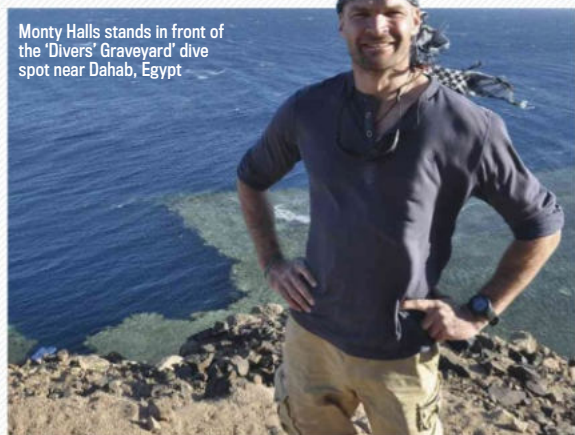


AS THE TRANSPORT system grinds to a halt this winter, spare a thought for people whose environment is truly hostile, like the Arctic's Sami. Anthropologist Chris Terrill (pictured) travels with them to witness their battle with the cold. Then, going to the other extreme, he journeys with Tuareg nomads into the Sahara, as they brave sandstorms and drought.

NOVEMBER

Monty Halls' Dive Mysteries

Channel 5, November TBC



➔ MARINE BIOLOGIST MONTY Halls can usually be seen mucking in with Cornish fishermen, but it was clearly a career path that didn't satisfy the daredevil in him. Here he investigates some enduring riddles, including a First World War safe rumoured to contain £50 million worth of gold, and Japan's own Atlantis. But to find the truth, he'll have to push his own diving skills to the limit, from freezing Lake Huron to the 'Divers' Graveyard', the Blue Hole near Dahab, Egypt.

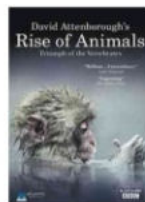
DVD & BLU-RAY



More Than Honey

Eureka, £9.92

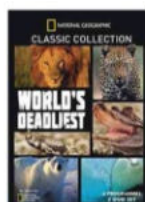
NOBODY'S SURE WHETHER it's pesticides, varroa mites or rival insects that are threatening bee populations, but we need their pollinating skills to keep our favourite plants going. Swiss film-maker Marcus Imhoof goes in search of answers.



David Attenborough's Rise Of Animals

Go Entertain, £12.28

SIR DAVID CHARTS the evolution of life with backbones, from simple fish to their domination of land, sea and air. The 500-million-year story links human life to ancient forms that make dinosaurs look like new-on-the-scene hipsters.



World's Deadliest

National Geographic, £7.91

WANT TO WATCH terrifying predators that could kill you with a single bite or blow of the paw? This is the boxset for you: six programmes showing wildlife at its most fatal. So go on, remind the kids that nature isn't always cuddly.

NOVEMBER

Ben Fogle's Animal Clinic

Channel 5, November TBC



AS THE NIGHTS close in, what could be nicer than settling down to watch something cute and furry? But besides Ben Fogle, this series also features the pets and more exotic patients that come to be treated at the University of Liverpool's Vet School. Where else can you see an orthopaedic surgeon operate on an endangered antelope?

24 NOVEMBER

Comet Of The Century

National Geographic, 24 November, 8pm



IT'S NOT OFTEN a TV special is scheduled to coincide with a kilometres-wide chunk of rock and ice hurtling towards Earth. But by the time this goes out, you might be able to see Comet ISON (pictured) lighting up the night sky brighter than a full Moon. Maybe. Astronomers will enlighten us on what ISON is made of and how we can see it.



LISTEN

BBC RADIO PROGRAMMES
WITH TIMANDRA HARKNESS

FROM 12 NOVEMBER

Gene Doping

BBC World Service,
12 November, various times

THE DOCUMENTARY SLOT investigates the latest twist in the race to enhance sports performance using science. Beyond chemical supplements, unorthodox training techniques or biomechanical augmentation, gene doping takes a step further into the athlete's body. Tim Franks looks at the potential and the pitfalls of rewriting the genetic code in the name of sporting excellence. Is it the ultimate way to cheat without being caught?



Could gene manipulation be the method athletes use to cheat in the future?

FROM 12 NOVEMBER

All In The Mind

BBC Radio 4,
starts 12 November, 9pm

RETURN OF THE series in which psychologist Claudia Hammond reports on anything and everything to do with the human mind. From mental illness to neuroscience and everyday issues like memory, each week she tackles topical stories and reports on new research. If you have a mind of your own, you'll find something of interest. If you don't, just do as you're told and tune in as they celebrate the programme's 25th anniversary.

FROM 13 NOVEMBER

Frontiers

BBC Radio 4,
starts 13 November, 9pm

EACH WEEK, *FRONTIERS* takes an extended look at some new research in science or engineering, giving listeners an opportunity to delve deeper than a magazine-style series allows. Interviewing researchers and hearing about the pitfalls and doubts as well as the exciting potential, the team of presenters get a portrait, not a snapshot, of what could be changing our world in the future.

FROM 18 NOVEMBER

The Infinite Monkey Cage

BBC Radio 4,
starts 18 November, 4.30pm

BACK FOR ANOTHER season, the series that invites scientists into an atmosphere of welcoming irreverence reunites comedian Robin Ince and Professor Brian Cox. If they do enough series, presumably they'll eventually reproduce Einstein's work and all of Ada Lovelace's pre-computer programs. But your radio might not last an infinite amount of time, so meanwhile just enjoy the entertainment.



Robin Ince (left) and Brian Cox return for more quirky questioning of scientists



TOUCH

SMARTPHONE & TABLET APPS
WITH CHRISTOPHER BRENNAN

Explore University Of Oxford Museums

Android 2.3 or later, iPhone, iPod touch, iPad
University of Oxford IT Services, Free



COMBINING FOUR WORLD class museums – the Ashmolean Museum, the Museum of the History of Science, the Museum of Natural History and the Pitt Rivers Museum – in one app, this guide gives you a great way to get the most from a visit to any one of them. There are floorplans and lists of scheduled exhibitions as well as images and descriptions of the most interesting objects at each of the museums. Usefully, you can tap on an item to see where it is located. Each museum has its own section so you can easily see what's on where.

Simple Rockets

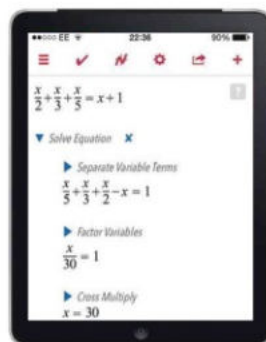
Android 2.2 or later
Isoperia, £1.26



BUILDING ROCKETS AND landing on the Moon is tricky and expensive at the best of times, but now you can practise on your Android phone. *Simple Rockets* is a game where you design your own space vehicle and pilot it out of the atmosphere. Build reality-defying rockets with huge fuel tanks, add landers and parachutes. There are orbiting levels and you can explore our Solar System or simply get to the Moon and back. It's a fun little app and easier than getting a job at NASA.

Math 42

iPhone, iPod touch, iPad
Cognition, Free



MATHS CAN BE incredibly complex and frustrating if you can't see how the numbers add up. *Math 42* is an app that can help with exactly this problem. Simply input an equation and *Math 42* can simplify it, factor the expression, arrange it and graph it too. You can break down even the most complex formula so that it's easier to digest. The app saves any equations you input and has a selection of exercises to test your brain.

CHRISTOPHER BRENNAN is a technology journalist and mobile app expert



PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY



Battlefield 4

PC, PlayStation 3, PlayStation 4, Xbox 360, Xbox One, £44.99

NOVEMBER IS THE month of the Annual First Person Shooter Derby, in which *Call Of Duty* squares off with *Battlefield* while jaded older gamers sigh into their memories of *Operation Wolf*. This year's *CoD* has an attack dog in it, while *Battlefield 4*'s multiplayer brings back Commander Mode, where select players get to boss everyone else about. *Battlefield 4* also boasts a mechanic called 'Levolution' – a portmanteau so hideous, we won't stoop to explain it here.



Gone Home

PC, £14.99

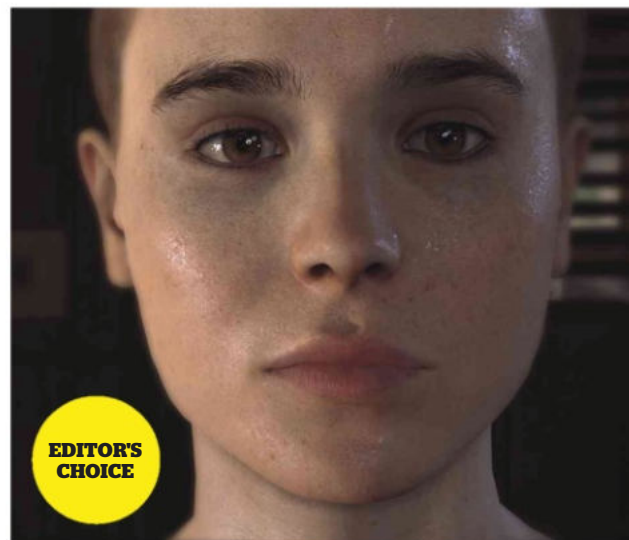
AFTER A YEAR of travelling around Europe, you return home to find an empty house. As rain drums down on the windows, you pick through familial minutiae in an attempt to discover where everyone is, and in particular what has happened to your 17-year-old sister. As with *Beyond: Two Souls* (see right), *Gone Home* is an exercise in interactive fiction, but here we remain firmly rooted in reality, uncovering a genuinely mature story that will leave you with much to think about.



Shelter

PC, £6.99

SHELTER IS AN eye-wateringly effective slice of emotional manipulation, dressed up as a particularly attractive indie game – think classic kids' cartoon *The Animals Of Farthing Wood* reborn in a minimalist style. As a maternal badger, it's your responsibility to shepherd your five cubs to a new home, gathering food for your family and guiding them past the dangers of predatory birds, forest fires and plain old starvation. It's a slender and linear affair, but that won't stop your heart from shattering when one of your babies is lost to the dark.



EDITOR'S CHOICE

Ellen Page and Willem Dafoe star in *Beyond: Two Souls*, the latest disconcertingly movie-like epic from renowned games designer David Cage

Beyond: Two Souls

PlayStation 3, £39.99



➔ AN UNEASY GULF lies between the land of video games and the land of cinema. Every so often someone tries to bridge the gap, and the results are usually controversial – not least thanks to purists on either side of the chasm, keen to maintain the isolation of their respective provinces.

Three years ago David Cage and Quantic Dream released *Heavy Rain*, perhaps the most divisive success story of the PS3 era. A pitch-dark tale of child abduction, serial killers and desperate fathers, it largely resembled an interactive movie. Now Cage has returned with the similarly filmic *Beyond: Two Souls* – a mysteriously disjointed ghost story focusing on a young runaway, Jodie, and her poltergeist companion, Aiden.

Like *Heavy Rain*, *Beyond* uses a system that sees players guide the movements of the principal characters, rather than controlling them in the traditional sense. The action unfolds via a series of self-contained scenes, and while it's impossible to 'fail' a stage, your choices within a given scenario determine the overall course of the narrative, which hops back and forth through time to major events in Jodie's turbulent life. You're given free rein to play as Jodie – human, physical and vulnerable – or as Aiden, whose fearsome powers can wreak havoc on the people and objects around him. For example, one scene finds Jodie on a train that's been boarded by the police. You can help Jodie quietly slip away, or you can have Aiden destroy the authorities in a destructive outburst that recalls Steven King's *Carrie*.

With Ellen Page and Willem Dafoe voicing the lead roles, *Beyond* has a high budget sheen, yet it's hard to shake the suspicion that this may be an uneven effort from Cage, whose work tends to be as ramshackle as it is risky and provocative. Even so, in a month of military shooters-by-numbers, it's bound to be worth a gander.

NEON KELLY IS DEPUTY EDITOR AT VIDEOGAMER.COM



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback

Scarcity

Why Having Too Little Means So Much

Sendhil Mullainathan and Eldar Shafir

Allen Lane **H** £20

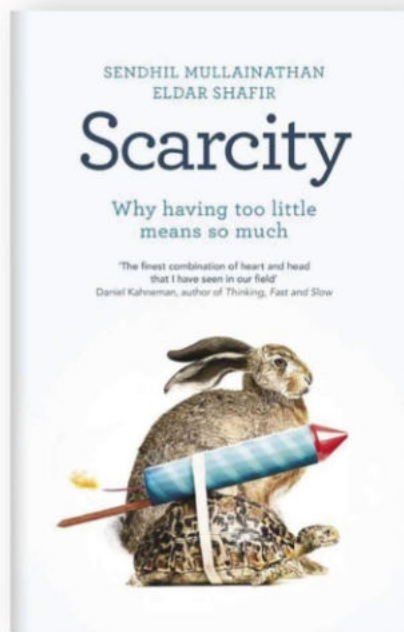
EDITOR'S CHOICE

THIS BOOK IS an exposé of the frailties of human decision-making. At first glance, the main thesis of this work co-authored by a Harvard University economist and Princeton psychologist may seem unsurprising: with limited resources, many of the decisions we make represent inefficient trade-offs. However *Scarcity* offers much more, by explaining how limited resources affect our decisions, with some surprisingly counter-intuitive insights.

Written in three sections, it explains the mindset that is induced by scarcity, the consequences of the vicious feedback loops that scarcity creates and finally, what to do to combat the scarcity problem. The authors demonstrate how a scarcity of the personal resources of both time and money distorts our reasoning by generating an involuntary focus and susceptibility to distractions. It is a problem of bandwidth: with scarcity, our capacity to attend efficiently to a number of parallel problems is compromised, so that we focus on the metaphorical trees without fully appreciating the extent of the wood.

Throughout, the authors use brilliant examples to elucidate the consequences of scarcity. We are told how 25 per

“When the poor borrow, they dig a narrowing tunnel of inopportunity with diminishing ability to change”



cent of US firefighter fatalities are due to individuals failing to wear their seatbelts on their way to a blaze. They know they should, but the urgency of the emergency compromises their health and safety training. We learn why you should build slack into a system to make it more capable of coping with the unexpected. And the analysis of pay-day loan schemes that flourish because of scarcity should in itself sound the death-knell for these companies that are now more prevalent than McDonald's. When the poor borrow, they dig a narrowing tunnel of inopportunity with diminishing ability to change.

Probably the most significant insight regards how scarcity affects the rich and poor. Not because of background or work ethics, but simply the ability to respond flexibly. The authors use the metaphor of packing a suitcase: the rich have much more room to cope.

Scarcity should be a wake-up call for those who want to enjoy life more. It also shows how we could manage the economy better to provide the best opportunities for those less fortunate.



PROF BRUCE HOOD is the author of *The Self Illusion*

MEET THE AUTHOR



Eldar Shafir

Where is scarcity in everyday life?

The obvious one would be trying to juggle a complicated and busy schedule. We're all used to the feeling of running out of time – one late meeting leads to three more; you get frazzled, you leave things until tomorrow. That psychology has a lot to do with managing scarcity.

How does scarcity affect our behaviour?

All types of scarcity – whether a lack of time, money, or friends – share common features. We all have a limited mental 'bandwidth' and when we don't have enough of something, it basically captures our mind. The poor, for example, are busy managing their moment-to-moment finances, while the lonely devote a lot of bandwidth to the fact that they feel lonely. So scarcity leaves less mind for other aspects of our lives.

How can we tackle scarcity?

We use the same bandwidth in everything we do – making sure we take our medication, remembering to save for retirement, controlling our temper when our kid annoys us. If we liberate bandwidth in one place, we have more available to use elsewhere. If you struggle with difficult finances, for instance, having help with the management of your savings can liberate bandwidth that might help you take your medication on time.

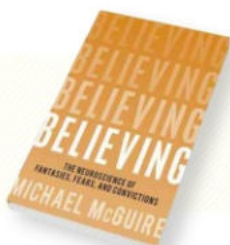
Did writing the book affect the way you live?

Yes, I try to leave some slack in my schedule so that when things go awry I have space to take care of it. My trick is to make a 'meeting with myself' so that I can clear my mind and liberate bandwidth.



MORE ON THE PODCAST

Listen to the full interview with Eldar Shafir at sciencefocus.com/podcasts



Believing

The Neuroscience Of Fantasies, Fears And Convictions

Michael McGuire

Prometheus Books **P** £12.84

IN *BELIEVING*, DR Michael McGuire tries to explain the biological origins and mechanisms that underpin how humans develop and sustain beliefs. It's undoubtedly an important topic, but unfortunately the diffuse nature of the subject often defeats his attempts.

Despite what the subtitle implies, McGuire delves into areas like evolution, psychology, and philosophy as well as neuroscience. He does so in a straightforward manner, but there are also many times when claims about beliefs are questionable.

For instance, McGuire discusses the dominance structure among male primates and how submissive and aggressive behaviour demonstrates how the animals 'believe' in the outcomes of actions. However, behavioural neuroscientists may interpret this differently – perhaps trial and error teaches them which behaviours elicit the desired reaction. The need for 'belief' isn't required.

It would be unfair to say McGuire has bitten off more than he can chew; he has made a decent attempt of it. *Belief* is interesting and readable despite its flaws.



DEAN BURNETT is a doctor of neuroscience and stand-up comedian



The Accidental Species

Misunderstandings Of Human Evolution

Henry Gee

University of Chicago Press **H** £18

FOR OVER 25 years the evolutionary biologist Henry Gee has worked at the journal *Nature* and he uses his insider's knowledge to explore popular misunderstandings about evolution in general and human evolution in particular. Although his jaunty style will not be to everyone's taste (Gee does funny voices, including Yoda), *The Accidental Species* is an excellent guide to our current knowledge of how we got where we are.

The book ranges over more than a century of the study of human evolution, but focuses on the palaeontological and genetic discoveries of the last decade, in particular *Homo floresiensis*, aka The Hobbit, and the interbreeding of humans and Neanderthals. At its heart is the idea that the evolution of humans was not inevitable and that we are not the pinnacle of evolution.

Gee also emphasises the poverty of the fossil record – there are no fossil traces of gorillas or tapeworms, for example – and the role of random events in shaping life on Earth. The final chapter, on the deep evolutionary roots of consciousness, is challenging, thought-provoking and highly recommended.



MATTHEW COBB is Professor of Zoology at the University of Manchester



Do Dogs Dream?

Nearly Everything Your Dog Wants You To Know

Stanley Coren

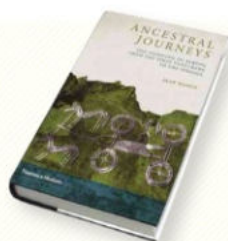
WW Norton & Co **P** £9.99

THE LITERATURE ON dogs has advanced rapidly since humourist Ogden Nash (1902-1971) wrote that, "The dog is man's best friend. He has a tail on one end. Up in front he has teeth. And four legs underneath." Today's bookstores have more books on dogs than you could throw a bone at. This one noses ahead of the pack in that the author is an academic psychologist (of people as well as dogs) and knows his stuff. The book is made up of 75 questions people ask about dogs ('do dogs dream?', 'what do dogs see?', and so on), each with a pithy yet considered response.

If, like me, you have dogs, you'll know a lot of this already, but I still learned things about my dogs I didn't know, such as how dogs interpret the human voice. This has already paid dividends in my relationship with my furry companions. As a handy practical guide it excels, though it's a little too fragmented for a long, leisurely read. An important message is that dogs are sensitive, intelligent creatures with mentalities similar to those of human toddlers. Understand this, and your relationship with your dog will be that much richer.



HENRY GEE is an evolutionary biologist and a senior editor of the journal *Nature*



Ancestral Journeys

The Peopling Of Europe From The First Venturers To The Vikings

Jean Manco

Thames & Hudson

H £19.95

HOW IMPORTANT WERE invasions in the early history of Britain? Migration has long been debated on the evidence of material culture and similarities between languages. Recently, DNA analysis has begun to clarify the issues. *Ancestral Journeys* is a dense history of Europe up to the period of the Vikings. It's based on Manco's wide-ranging survey of the latest genetic analysis of ancient and modern human and animal DNA.

For example, Y-DNA (found only in males) was taken from two groups of British men in the Wirral peninsula and west Lancashire. The first group could prove two generations of residence, the second went back much

further. Their surnames were recorded in the region in medieval times and had greater Scandinavian ancestry than the first, similar to that found today in Norway and the Isle of Man. This makes sense because Viking warriors, after their expulsion from Dublin in 902, seized the Isle of Man and also populated the Wirral and west Lancashire.

Manco is strong on research, less so on making her findings accessible. Nonetheless, this is an important work.



ANDREW ROBINSON is the author of *Cracking The Egyptian Code*

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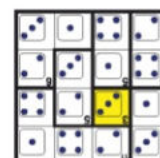


Our Pinterest site brings you a stream of jaw-dropping photos. Our boards are full of the very best science and nature pictures and previously published images from our renowned Megapixel section.

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Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, illegible or fraudulent entries. The closing date and time are as shown on page 135. Entries received after that will not be considered. Entrants must supply their full name, address and daytime phone number. Immediate Media (publisher of *BBC Focus Magazine*) will only ever use personal details for the purposes of administering this competition unless you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemediaco.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown on the Crossword page. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. The name and county of residence of the winners will be published in the magazine within three months of the closing date. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.



MINDGAMES PUZZLE
SOLUTION
No cheating! Don't look at this until you've attempted the puzzle on p135.



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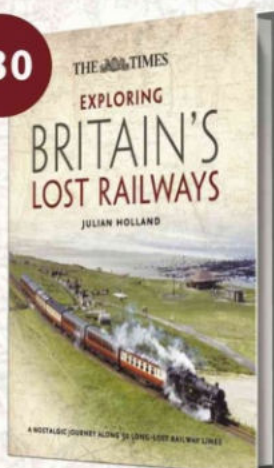
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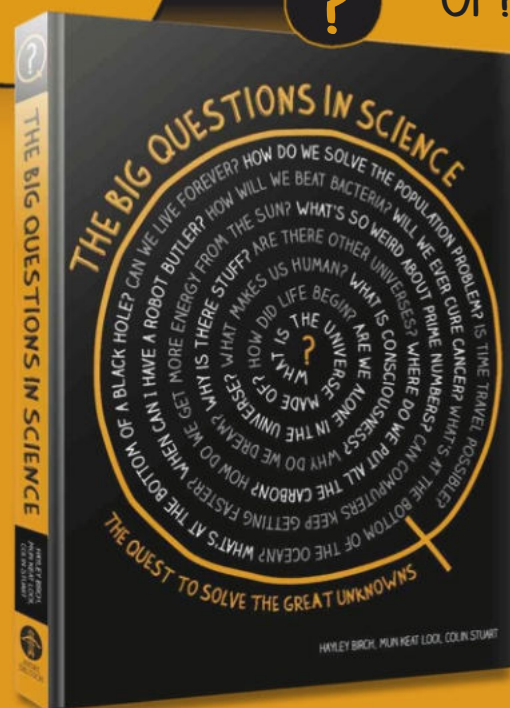
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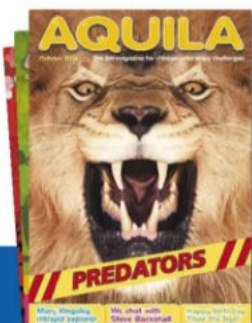
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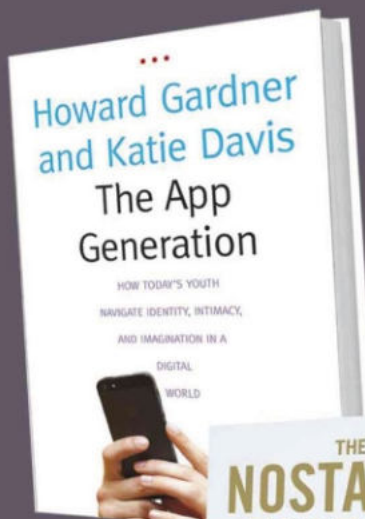


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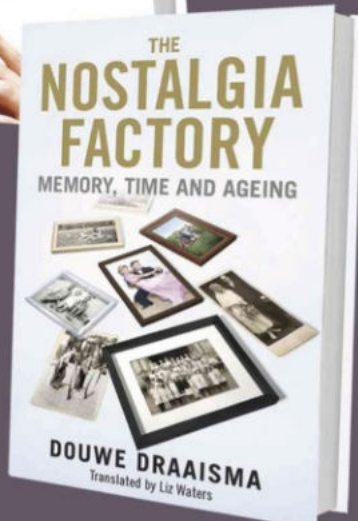
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The Nostalgia Factory

Douwe Draaisma, a renowned memory specialist, here focuses on memory in later life. Writing with eloquence and humour, he explains neurological phenomena without becoming lost in specialist terminology. Draaisma weaves stories and science into a compelling description of the terrain of memory and a celebration of the unique qualities of the ageing mind.

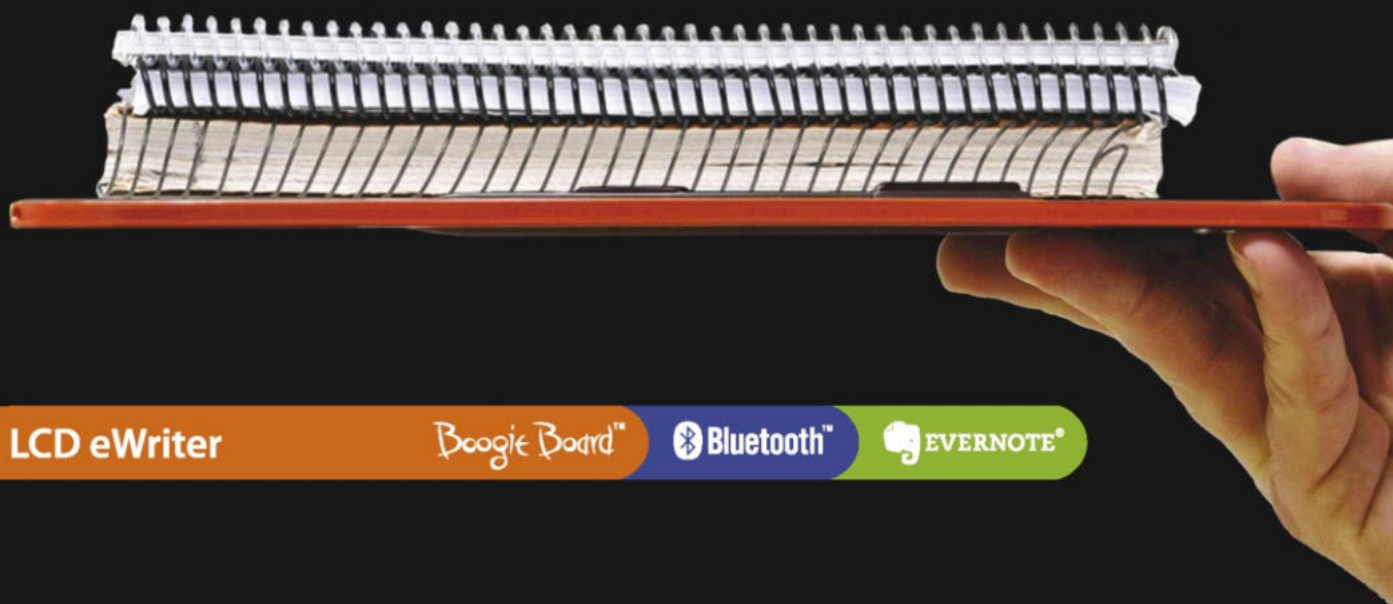
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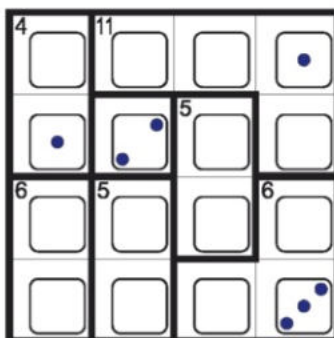
MINDGAMES



Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

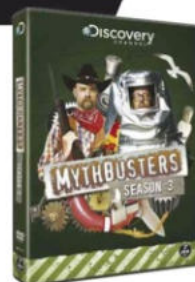
When complete, each row and column contains a 1, 2, 3 and 4-spot die and each shape contains the total number of spots shown. Complete the partial solution. (Beware of a trick...)



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The first five correct entries win a copy of *MythBusters Season 3* on DVD (Discovery Channel).

Post your entry, marked 'Prize Puzzle 261', to: *BBC Focus Magazine*, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 14 November 2013. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.



See bottom of p128 for terms and conditions. Congratulations to Geraldine Darlington (Swindon), Robert Stewart (Keynsham), Tim Earl (Hove) and Peter Haworth (Bristol) who answered August's Prize Puzzle correctly to each win a copy of *Walking With Dinosaurs* on DVD.

Q1

Chloe's trouser pocket is empty, and yet has something in it. What is it? (The answer is not 'air'.)

Q2

What connects Budapest, a wallaroo, smog, a tangelo, avionics and the Bakerloo Line?

Q3

Complete the white squares so that they contain 1 to 16 inclusive, and each row and column adds up to the total shown.

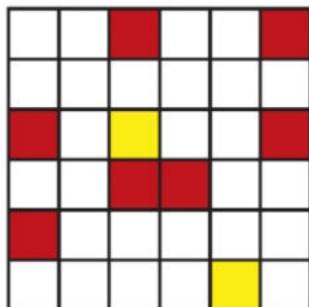
		5		20
	10		7	46
16			6	36
				34
38	28	43	27	

Q4

Finish the sentence: 'Tesseractdecades' is the longest word you can type...

Q5

Complete the grid so that each row and column contains three red and three yellow squares, but does NOT contain a run of three of either colour.



Q6

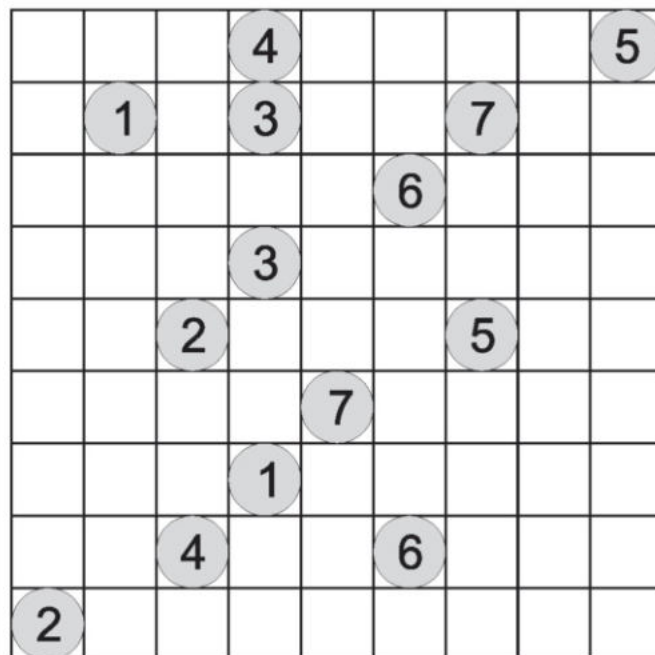
How many prime numbers are one less than a cube number?

Q7

Magician Simon Lovell spent years asking people he met to think of any playing card, but in a certain way, and found that the Four of Clubs was the most popular choice. What exact question did he ask?

Q8

Draw lines to match up the circles so that 1 is connected to 1, 2 is connected to 2 and so on up to 8. The eight lines cannot touch or cross other lines or themselves. The lines run horizontally and/or vertically through the middle of the white squares, and you may make 90° turns in the middle of a square. Lines cannot pass through the numbered squares. Beware – the shortest connection is not always the correct one.



SOLUTIONS

Q1) Usually, 'Ace of Spades or Queen of Hearts' are the most popular 'guess' a card choices. He asked people to think of a card that they thought he'd be unlikely to guess.
Q2) See illustration on p128.

Q3) Only one, 7 (one less than 8). Outline proof: let $P = X^3 - 1$; rewrite this as $P = (X-1)(X^2 + X + 1)$. P is prime (i.e. has no factors except 1 and P) so $X-1=1$, or $X=2$ hence $P=2^3-1=7$.

Q4) Row by row: 4 9 5 2; 15 10 14 7; 16 standard touch-typing on a QWERTY keyboard.
Q5) Row by row: YRYRR, YRYRR, YRYRR, YRYRR.

Q6) It has a hole in it.
Q7) 'Portmanteaus' formed by merging two words (Buda/Pest, wallaby/kangaroo, 'smoke/fog, tangerine/pomelo, aviation/electronics, Baker Street/Waterloo).

QUICK QUIZ

Test your knowledge of the Nobel Prize

Q1

What nationality was Alfred Nobel, after whom the prizes are named?

- a) German
- b) Danish
- c) Swedish

Q2

Which of these scientists has been awarded a Nobel Prize?

- a) Dmitri Mendeleev
- b) Stephen Hawking
- c) Niels Bohr

Q3

Which is not a Nobel Prize?

- a) Nobel Prize in Physics
- b) Nobel Prize in Biology
- c) Nobel Prize in Chemistry

Q4

In what year was Albert Einstein awarded his Nobel Prize?

- a) 1901
- b) 1911
- c) 1921

Q5

Who is the only person to win a Nobel Prize in two different sciences?

- a) Marie Skłodowska-Curie
- b) Max Planck
- c) Alexander Fleming

Q6

When were James Watson, Francis Crick and Maurice Wilkins honoured for their discovery of the structure of DNA?

- a) 1952
- b) 1962
- c) 1972

Q7

How old was William Lawrence Bragg when he was awarded a Nobel Prize in 1915?

- a) 25
- b) 30
- c) 35

ANSWERS:

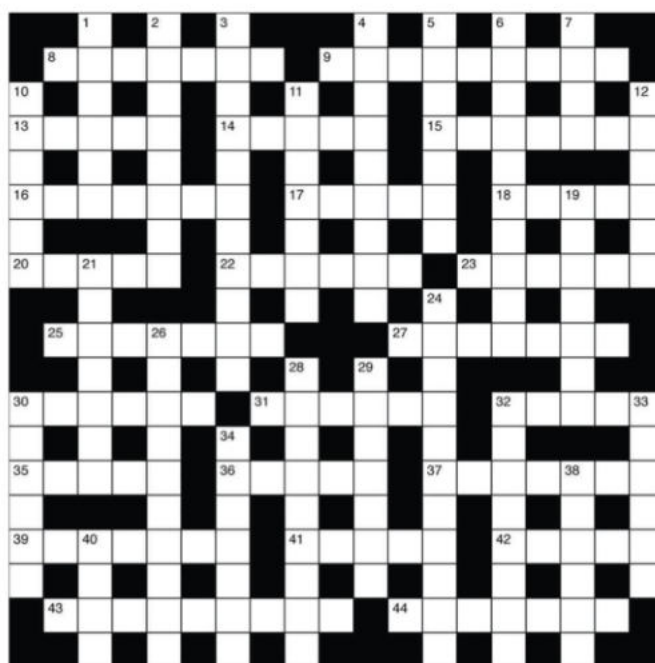
1c, 2c, 3b, 4c, 5a, 6b, 7a

YOU ARE:

- 0-3 A wooden spoon winner
- 4-5 An Ig Nobel Prize winner
- 6-7 A Nobel Prize winner

FOCUS CROSSWORD No 157

EVERY MONTH, A NEW CHALLENGE SET BY AGENT STARLING



ACROSS

- 8 Behold animal coming round for a purgative (7)
- 9 Ordered retro beam - it shows amount of pressure (9)
- 13 Strength of a small tree (5)
- 14 Rinse out sap (5)
- 15 Discipline at school turned out nice at church (7)
- 16 Element that can hum bits of composition (7)
- 17 New aim - to leave as an adult (5)
- 18 Chap left nine in a spiral (5)
- 20 Data transmitter doesn't finish the journey (5)
- 22 Controlling program for a motorist (6)
- 23 American reptile began as a flower (6)
- 25 A looser form of spray (7)
- 27 Sailor only gets seafood (7)
- 30 Volunteers to strike one Pacific island (6)
- 31 Fuel causes objection on a couple of points (6)
- 32 Musical game... (5)
- 35 ... about musical furniture (5)
- 36 Wood and sand in report (5)
- 37 Rodent has label showing potential difference (7)
- 39 Double the energy, with new pills to get in shape (7)
- 41 Check gold key and object (5)
- 42 Racket is one solution (5)
- 43 In favour of adjusting scores in CPU (9)
- 44 Get upset at last order for cut glass (7)

DOWN

- 1 Half the diameter of a bone (6)
- 2 Spy gives copper the French bit of material (8)
- 3 Figure makes torrent head in another direction (11)
- 4 Waiter ran off to get the cheapest thing on the menu (9)
- 5 Kitty finally shot off to a Wi-Fi area (7)
- 6 Help repair broken printer, say (10)
- 7 Infernal plant is included (4)
- 10 Line on map shows one wild boars (6)
- 11 Sprain treated with one painkiller (7)
- 12 Persian king covers queen in kisses to get bearings (6)
- 19 Solve a clue, finding sodium in gaps (7)
- 21 Waste pipe shifting earth behind ancient city (7)
- 24 Reportedly see a politician, building (11)
- 26 Peace tours organised beyond our atmosphere (5,5)
- 28 True Roman solution, using a bit of a fraction (9)
- 29 Heat cod incorrectly, and it's terminal (7)
- 30 Watch the heart (6)
- 32 Mark first becomes a pioneer (8)
- 33 Vegetable found on new land (6)
- 34 Former pupil sees poetry as a counterpart (7)
- 38 Beast has article to mail off (6)
- 40 Bird having fun (4)

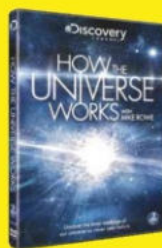
SOLUTION TO CROSSWORD No 154

Bill Maddison, Philip Cooper, Christine Gilbert, Roberta McCutcheon and Stephen Millard solved issue 258's puzzle and each receive a copy of *Genius* by Jack Challoner.



WIN! HOW THE UNIVERSE WORKS ON DVD

The first five correct solutions drawn will each win a copy of *How The Universe Works* on DVD (Discovery Channel, £18.32). Entries must be received by 5pm on 14 November 2013. See below for more details.



YOUR DETAILS

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Post entries to BBC Focus Magazine, November 2013 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to november2013@focuscomps.co.uk by 5pm on 14 November 2013. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 128. Immediate Media, publisher of BBC Focus Magazine, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.



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for iPhone 5 + 5s



SecondSkin
Silicone Case
for iPhone 5 + 5s



AeroGrip
Snap-on Case
for iPhone 5 + 5S





INTO THE FUTURE

STEPHEN BAXTER

Engineering on a planet-wide scale could one day save the human race

THE TENTH OF October 2013 saw the 100th anniversary of the completion of the Panama Canal. With a total length of 77km (48 miles), the Canal today permits around 15,000 ships a year to pass across the Isthmus of Panama via an artificial lake 26m above sea level. This was a tremendous piece of engineering, requiring the removal of some 400 million tonnes of material in a hazardous and disease-ridden environment. It was a dramatic manipulation of the geography of the Earth itself. Humans had opened up a mid-latitude seaway between the Atlantic and Pacific for the first time since the continents of North and South America, originally separate, had naturally collided some three million years earlier.

But Panama has been by no means the largest engineering manipulation on Earth. In fact, when Panama was opened, the longest canal ever constructed was already very ancient: the Chinese Grand Canal, between Beijing and Hangzhou, fully opened up around the year AD 600, is a staggering 1,776km (1,103 miles) long.

In terms of sheer volume Panama has been dwarfed by other ongoing engineering projects, as we excavate and dump across the planet. The natural processes of the planet remove some 24 billion tonnes of material from land surfaces per year, carried off by erosion and subsidence and washed away by rivers

into the sea. But even the lowest estimates of the movement of rock and soil by humans beat this natural rate easily. A Worldwatch Institute paper published in the 1990s estimated that as many as 30 billion tonnes of non-fuel minerals are dug out of the ground

each year, much of it sand or gravel to be used as fillers for concrete. To that must be added the amount shifted in construction, dredging and reclamation, along with other enterprises.

Some of the results are startling indeed. The famous Barringer 'Meteor Crater' in Arizona, 1,200m across and 180m deep, is smaller for example than the Bingham Canyon open-pit copper mine in Utah. The mine is more than 2,000m across and required the removal of seven times the amount of material required to complete Panama. We dig holes that dwarf meteor craters: we are indeed a species that shapes its planet.

It's possible we will one day do much more. A few years before the opening of Panama, American astronomer Percival Lowell believed that a planet-wide engineering enterprise was exactly what he was seeing



We've been engineering on a global scale for decades - it's a feat that could save us from ourselves

"Such super-Panama canals would have had to be thousands of kilometres long, stretching across the face of the planet"

through his telescope on the surface of Mars. He imagined he saw tremendously long 'canals', straight-line markings on the planet's surface, with dark 'oases' where the canals intersected. Such super-Panamas would have had to be thousands of kilometres long, stretching across the face of the planet. If these were anything like terrestrial canals they would probably be too narrow to be seen directly, but Lowell suggested he was seeing wider bands of vegetation stimulated by the presence of the water. Lowell imagined not a transport system like Panama, but a hydrological system designed to bring water from the polar ice caps to a desiccating planet: the project of a global Martian civilisation, co-operating to save its world.

Lowell was sadly wrong. Images from the first spaceprobes to Mars showed no sign of Lowell's canals - though they did discover, in the Valles Marineris, a natural system of canyons some 4,000km (2,485 miles) long.

But Lowell's vision of a civilisation working together to engineer its world to save itself is not unlike our own modern 'geoengineering' projects. These are proposals to reshape the world on a global scale, not to extract its mineral wealth, but to stabilise it as an abode for life and civilisation.

Perhaps what Lowell saw, peering earnestly at blurry planetary visions through his telescope eyepiece, wasn't so much a vision of Mars in the present, but of our own world in the future. ■

STEPHEN BAXTER is a science fiction writer whose books include *The Science Of Avatar* and the *Northland* series

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